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High energy, low energy density, radiation-resistant optics used with micro-electromechical devices

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Inventor(s):

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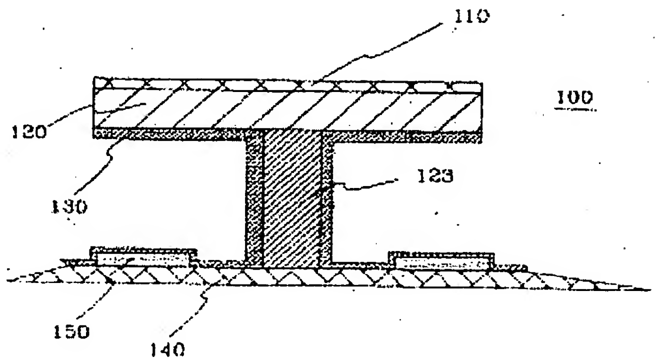
The present invention includes methods and devices that improve the radiation-resistance of a movable micromechanical optical element. In particular, a radiation-resistant layer is added to a movable micro-mechanical optical element, suitable to reduce the surface and bulk material changes to the element that result from exposure to pulsed laser energy densities less than 100 micro-joules per square centimeter and at wavelengths less than or equal to about 248 nm.



CLAIMS

[Claim(s)]
[Claim 1]
It is how to improve resistance to damage caused by radiation in an optical minute electric machine system (MEMS) containing at least one movable modulation element, and said damage is produced from a low fluence and an addition pulse of electromagnetic radiation of short wavelength,
At least one radiation resistance layer is formed on the front-face said at least one movable modulation element side, ******, a described method.
[Claim 2]
A described method which is reflexibility substantially in operating wavelength in a method according to claim 1 in which said radiation resistance layer is shorter than about 248 nm or it.
[Claim 3]
In a method according to claim 1, said radiation resistance layer, An oxide (Hf_aO_b) of hafnium, fluoride of magnesium (Mg_eF_x), A described method containing at least one of fluoride (La_pF_x) of a lantern, an oxide (aluminum_sO_t) of aluminum, an oxide (Si_yO_x) of silicon, or fluorides (Li_kF_z) of lithium.
[Claim 4]
A described method with which said radiation resistance layer contains an oxide of hafnium, an oxide of aluminum, or an oxide of silicon in a method according to claim 1.
[Claim 5]
A described method with which said radiation resistance layer contains fluoride of magnesium, fluoride of calcium, or fluoride of lithium in a method according to claim 1.
[Claim 6]
A described method which is a said radiation resistance layer placing-layer by the side of a front face of said movable modulation element in a method according to claim 1.
[Claim 7]
A described method with which said placing radiation resistance layer is activated in a method according to claim 6.
[Claim 8]
A described method with which said placing radiation resistance layer comprises placing element boron and carbon in a method according to claim 7.
[Claim 9]
Including being the method according to claim 1 and forming further two or more radiation resistance layers, said two or more radiation resistance layers, a placing layer by which an oxide of hafnium, an oxide of aluminum, an oxide of silicon, fluoride of magnesium, fluoride of calcium, fluoride of lithium or boron, and carbon were activated, and ** -- a described method of at least one inside to include.
[Claim 10]
A described method in which said radiation resistance layer has a thickness of about 30 to 70 nm in a method according to claim 1.
[Claim 11]
A described method in which said radiation resistance layer has a thickness of about 2 to 50 nm in a method according to claim 1.
[Claim 12]
A described method in which said radiation resistance layer has a thickness of about 50 to 100 nm in a method according to claim 1.
[Claim 13]
A described method with which said movable modulation element contains aluminum in a method according to claim 1.
[Claim 14]
A described method with which said movable modulation element includes material of one or more of a silicon nitride, silicon, titanium, tantalum, or the tungsten in a method according to claim 1.
[Claim 15]
A described method in which said material composition of on a method according to claim 1 and as opposed to said radiation resistance layer is the average bulk composition from the upper part of said layer to the lower part of said layer.
[Claim 16]
A described method in which said material composition to one with said two or more radiation resistance layers arbitrary in a method according to claim 3 is the average bulk composition from the upper part of said layer to the lower part of said layer.
[Claim 17]
A described method which is the method according to claim 1 and includes forming further a reflecting layer containing one or more of aluminum, silver, and the gold before forming said radiation resistance layer.
[Claim 18]
A described method which said movable modulation element has the rear-face side, and includes forming at least one antireflection layer on said rear-face side further in a method according to claim 1.

[Claim 19]
A described method with which said antireflection layer contains CaF_2 or MgF_2 in a method according to claim 18.
[Claim 20]
A described method with which said antireflection layer contains fluoride of magnesium or calcium in a method according to claim 18.
[Claim 21]
A described method in which said antireflection layer has a thickness of about 15 to 80 nm in a method according to claim 18.
[Claim 22]
A described method in which said antireflection layer has a thickness of about 40 to 60 nm in a method according to claim 18.
[Claim 23]
A described method in which said antireflection layer has a thickness of about 60 to 80 nm in a method according to claim 18.
[Claim 24]
A described method with which said movable modulation element transmits electromagnetic radiation in a method according to claim 1.
[Claim 25]
In a method according to claim 24, said movable modulation element is a transparent described method substantially to wavelength of 248 nm or less.
[Claim 26]
A described method with which said movable modulation element contains an oxide of silicon in a method according to claim 24.
[Claim 27]
A described method with which said radiation resistance layer contains one layer in a method according to claim 24.
[Claim 28]
A described method with which said radiation resistance layer contains two or more layers in a method according to claim 24.
[Claim 29]
A described method with which said radiation resistance layer contains fluoride of magnesium or calcium in a method according to claim 24.
[Claim 30]
A described method in which said radiation resistance element is an oxide of two, aluminum beyond it, or silicon in a method according to claim 24.
[Claim 31]
A described method which is the method according to claim 1 and includes carrying out flattening of said front-face side further before forming said radiation resistance layer.
[Claim 32]
A described method with which said front-face side has good RMS surface smoothness from 2 nm after said flattening in a method according to claim 31.
[Claim 33]
A described method with which said front-face side has good RMS surface smoothness from 1 nm after said flattening in a method according to claim 31.
[Claim 34]
A described method with which said front-face side has good RMS surface smoothness from 0.5 nm after said flattening in a method according to claim 31.
[Claim 35]
A described method which contains CPM which uses an abrasive grain of a size in which said flattening is smaller than 300 nm in a method according to claim 31.
[Claim 36]
A described method with which said flattening contains CPM which uses an abrasive grain with a size of about 70 nm in a method according to claim 31.
[Claim 37]
A described method with which said flattening contains CPM which uses an abrasive grain with a size of about 50 nm in a method according to claim 31.
[Claim 38]
It is at least one movable modulation element of an optical minute electric machine system (MEMS),
The front-face side,
At least one radiation resistance layer on said front-face side,
******, the above-mentioned movable modulation element.
[Claim 39]
The above-mentioned element which is reflexibility substantially to radiation in operating wavelength in the element according to claim 38 in which said radiation resistance layer is shorter than about 248 nm or it.
[Claim 40]
The above-mentioned element which is transmission nature substantially in operating wavelength in the element according to claim 38 whose said movable modulation element and said radiation resistance layer are shorter than about 248 nm or it.
[Claim 41]
In the element according to claim 38, said radiation resistance layer, The above-mentioned element containing at least one of a hafnium acid ghost (HfO_2), magnesium fluoride (MgF_2), an aluminum oxide ($aluminum_2O_3$), a silica dioxide (SiO_2), or lithium fluorides (LiF_2).
[Claim 42]
A described method with which said radiation resistance layer contains an oxide of hafnium, an oxide of aluminum, or an oxide of silicon in a method according to claim 38.
[Claim 43]
A described method with which said radiation resistance layer contains fluoride of magnesium, fluoride of calcium, or fluoride of lithium in a method according to claim 38.

[Claim 44]
A described method which is a said radiation resistance layer placing-layer by the side of a front face of said movable modulation element in a method according to claim 38.
[Claim 45]
A described method which is a flat surface where said front-face side has 2 nm or better RMS in a method according to claim 38.
[Claim 46]
It is the element according to claim 38, and is a pan,
The rear-face side of said movable modulation element,
At least one antireflection layer formed on said rear-face side,
******, the above-mentioned element.
[Claim 47]
It is the element according to claim 45, and is a pan,
A non-movable substrate under said movable modulation element which said moving element combines in movable,
At least one antireflection layer formed in said a part of non-movable substrate,
******, the above-mentioned element.

[Translation done.]

* NOTICES *

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1.This document has been translated by computer. So the translation may not reflect the original precisely.
2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[Field of the Invention]
[0001]
(Field of invention)
This invention contains the method and element which improve the radiation resistance of a movable minute machine optical element. . Produce, when the owner pulsed laser energy of an energy density smaller than the 100-micro joule per square centimeter is especially exposed in the wavelength of about 248 nm or less. A radiation resistance layer suitable for decreasing change of the surface in an element and a bulk material is added to a movable minute machine optical element.
[Background of the Invention]
[0002]
(The background of invention)
The optical minute electric machine system (MEMS) or the spatial-light-modulation machine (SLMs) is used in a movie, a presentation projector, and television, in order to generate the image for a televiewer today. A pattern usually appears on the wide range surface like a projection screen or a viewing plate. In such applications, visible wavelength light (400 to 800 nm) is used. MEMS is used again as a switch which turns the beam of light to other optical courses from one optical course. In switching application, normal use of not the ultraviolet radiation that is shorter wavelength but the light of a visible wavelength is carried out.
[0003]
this invention person and their coworker applied SLMs to the micro lithography process included in semiconductor device manufacture recently. SLMs is more detailed, smaller, and it is used in order to generate the picture packed more to high density. In order to describe the picture packed small and with high density, it is required to use a light of short wavelength shorter than the inside of an ultraviolet spectrum or it. Electrostatic activity-ization is used in order to deflect a micro mirror. In order to generate power, it is generated between the electrodes whose voltage is two. One electrode is static and other electrodes are attached to an actuator like a movable micro mirror, for example. For example, SLM which has an array of an actuator used in a mask writing tool or a chip fabrication tool, It is loaded with a specific pattern, and an actuator is in the state or the state where an address is not carried out by which the address was carried out here, when relaying or transmitting the beam of electromagnetic radiation on a manufactured product. The beam of this relayed electromagnetic radiation contains the stamp of the pattern which should be printed on the above-mentioned manufactured product. This pattern may be the subset of a pattern or the perfect pattern which should be printed on a mask or a chip, respectively.
[Description of the Invention]
[Problem to be solved by the invention]
[0004]
Therefore, the opportunity to develop the method and element which are fitted so that SLMs may be used with short wavelength arose, having understood the problem which uses SLMs with the light of short wavelength containing wavelength shorter than about 248 nm or it, and prolonging the usefulness and the life of a MEMS element effectively.
[Means for solving problem]
[0005]
(Outline of invention)
This invention contains the method and element which improve the radiation resistance of a movable minute machine optical element. . Produce, when the owner pulsed laser energy of an energy density smaller than the 100-micro joule per square centimeter is especially exposed in the wavelength of about 248 nm or less. A radiation resistance layer suitable for decreasing change of the surface in an element and a bulk material is added to a movable minute machine optical element.
[0006]
(DETAILED DESCRIPTION)
The following detailed explanation is given with reference to drawing 1-9. A desirable embodiment is described in order to indicate the technology of this invention, and it does not restrict the range of the claim defined here. Various equivalent change will be recognized on the occasion of the following explanation by the engineer of this field.
[0007]
The micro lithography SLMs uses the array of a very small precise movable optical modulator, or an optical element like a mirror. A reflected-light study element may be tens of microns from several microns at one side. The SLM array containing such two or more elements can be from a thing smaller than one centimeter on one side even to tens centimeters in one side. The thickness of an optical element may be the thickness of 1 - 2 microns, or 350 to 700 nm, or may be more thinly [than this] thick. Desirable surface smoothness (buckling of the mountain of a single reflective element to a valley) may be precise about four to ten nm over 16 microns, and may be more precise. The both sides of surface surface smoothness and mechanical stability (the resistance to an edge curl is included) may be required. The lives with a desirable element may be 10 billion or 100 billion pulses from 1 of radiation, and many mechanical deflections. It is because an element creates a desirable micro lithography pattern, so it is adjusted.
[0008]
As compared with SLMs used in order to generate the picture for a televiewer, the micro lithography SLMs uses the light of

short wavelength rather than having energy per higher photon. The photon of higher energy has high capability rather than changing materially the surface of an optical element, and the physicochemical quality of bulk. It is observed that a high-energy-light child may change the optical property of an optical element in the light of short wavelength between development. Generally, the net change per [in the character of the reflector in a fixed fluence] photon is in inverse proportion to the wavelength of exposure electromagnetic radiation. Generally, the change per [in the surface of an optical element and/, or bulk character] photon is so larger that the wavelength of electromagnetic radiation is shorter. The change as a result in the bulk of an optical element and the character of material is irreversible, and cumulative. The change in the character of a micro lithography SLMs optical element is desirably irreversible. It is because the quality of the picture which change decreased fidelity, therefore was generated is lowered.

[0009]

A reflected-light study element is formed from a desirable material of high reflectance like aluminum. In a larger pulse ratio than 500 Hz and the wavelength of 248 nm or less, the exposure high-energy-light child who has a pulse is reflected from the surface of a movable optical element in an energy density smaller than the 100-micro joule per square centimeter. The photon which collides may affect the surface and the bulk character of an optical element mutually.

[0010]

Use of the reflection SLM is not restricted to using such SLM for laser pattern generation. It has intention of the range of a claim so that movable and static, other reflections, and transmission optical element out of use of such technology for the pattern generation based on the laser in an energy density and wavelength which are specified here may be included. Although there are the photonic switch and MEMS shutter array for a scanning mirror and communication as an example, it is not limited to these.

[0011]

It depends on the surface and the bulk character of an optical element for the type of change which can be predicted heavily. When electric conduction, an insulation, and the charge of half-guide members are exposed by the light of the same wavelength and a fluence, reactions differ. Change caused with the photon in the bulk and surface properties of an optical element can be measured directly or indirectly. The material change to a mirror can measure quantity directly by the granularity of hardness, chemical composition, and the surface, the loss of material, the change in thickness, or change in the form of an optical element. The change in the optical property of a mirror can measure quality through the change in reflectance, regular reflectance or non-regular reflectance, a luminosity, or contrast.

[0012]

It is observed that the regist-patterning processing used in order to define the optical element of SLM leaves a residual substance after that so that exposure by environment may be so. A resist process or residual carbon from other sources is observed on the surface of an optical element. Sample structure (what is called a sample with a mirror) contained 350-nm-thick aluminum / magnesium / silicon alloy film on photoresist. The annealing of such sample structures was carried out in 160 ** for 12 hours. What is called structure "processed" was exposed by 90 million of a 248-nm laser beam, 2.5 mJ/cm^2, and the 25-ns pulse in 500 Hz. Other sample structures (what is called a mirror-less sample) had 1000-nm-thick aluminum / magnesium / silicon alloy film without annealing on the single crystal silicon substrate. Some mirror-less samples were processed when low energy density and a high energy laser pulse were exposed. Sample structure was analyzed.

[0013]

In two monolayers of the surface upper part, analysis of the sample showed existence of high carbon relatively. Carbonaceous content was decreasing substantially in about 9 nm inside from the surface. The layer of the aluminum oxide seemed to have mixed with carbon. The particle of the alloy was observed in the surface and considered to be a by-product of sputtering adhesion so that it might be predicted. The particle appeared in the size of the order of 20 to 25 nm. In some processed samples, the particle of the alloy was emitted from the surface, and it was removed finely, and seemed to leave the surface which leaves without completely moving, without changing an adjoining particle, and includes a hole 20 - 30 nanometers deep and which is not even. Desorption of the particle from the surface An H. helluva alder, L WIDOMAN, and H.S. Kim, "The relevance to the photophysical processing and atomic layer processing in a low fluence UV laser material interaction", It is in agreement with an experimental result without advanced MATERIARUSU Fau optics and electronics, Vol.2, 31 - 42 pages, and the relation to this invention of 40 (1993).

[0014]

Surface hardness of an unsettled structure was also measured with finishing [processing]. When a result analyzed as power applied by a hysterics TIRON try boss Co-op TM analyzer using AFM was combined, it was thought that the surface of a processed sample was harder than the surface which resists by osmosis by analysis investigation, therefore is not processed. A film considered that a TEM picture of a processed sample with a mirror is the non-same quality physicochemically, and is mixing of aluminum and oxygen with much carbon, magnesium, and silicon was shown. It was surmised that a loss of material (oxygen and particle) and combination of strengthening of surface hardness were connected with a curve of five to 20 nm observed covering an element face with a width of 16 microns of mirror structure after processing.

[0015]

In accordance with these observation to these observation, a method for processing of the optics MEMS of a schedule [in / about 248 nm] exposed by wavelength shorter than it was developed. Before flattening buffing removes a mirror from a resist located under mirror structure, it may be applied to a mirror, and more generally, it may be applied to optical MEMS structure of a schedule exposed by short wavelength. As for CMP buffing, in order to make surface granularity small, it is desirable to use a very small abrasive grain. Buffing may be adopted so that fully for removing a particle and smoothing from the surface of the optics MEMS. It is thought that a particle has change and a relation after exposure to the surface and bulk character of a reflected-light study element. Buffing may be adopted so that fully for removing a particle from the surface of a mirror. It is expected that a slurry based on suitable pH and viscosity, and other silica that sets and has a particle with a size of 50 or 70 nm is helpful. More generally 300 nm or a smaller abrasive grain may be helpful for a size of particles. Other slurries which use different abrasive soap may often be equally helpful. being developed by ACSI group of ATMI and Inc. — brand-name Plana Kem, OS, and a series oxer -- ide -- a slurry currently sold in the name of a SMP slurry has a desirable small grain size. Flattening composition for structure of these slurries to remove US,5,993,685,B and a metal membrane (November 30, 1999), It is thought that it is based on research explained to flattening composition and a method (November 27, 2001) for removing flattening composition (July 31, 2001) for removing No. 6,267,909 and a metal membrane and No. 6,322,600, and an internal layer dielectric

film. Buffing which removes about 5–30, 5–20, 5–10, 10–20, 20–30, a range containing 50 to 100 nm, 5, 10, 20, 30 and 50, 100 nm, or material not more than it by composition of the optical MEMS surface may be performed. A marginal size of buffing changes with surface configurations. Surface granularity can be observed and measured using an atomic force microscope.
[0016]
Drawing 9 shows an embodiment of a movable microoptics element. A movable optical element may be Motoko Kagami in a spatial-light-modulation machine (SLM) array. This mirror lets the range of a deflecting angle pass, or may be deflected by the binary number maximum or zero deviation. Motoko Kagami's deviation may be linearity or non-linearity as a function of an input signal.
[0017]
In drawing 9, generally the movable optical element 10 is a rectangle, and is supported on 1 set of torsion hinges 60 along with one of omitted portions. Movable optical elements may be arbitrary forms, for example, may be a polygon, and circular or an ellipse form. The above-mentioned hinge is supported by the support element 50. The movable minute element 10, the torsion hinge 60, and a support element may comprise the same material that is aluminum or a different material; for example. The substrate 20 contains the electric conduction electrodes 30 and 40. The electrodes 20 and 30 are connected to a circuit (not shown) made in the substrate 20. If potential difference is applied between one and the above-mentioned optical element of an electrode, electrostatic force will be accumulated and, thereby, it will be electrostatically drawn by the above-mentioned movable optical element (it deviates).
[Best Mode of Carrying Out the Invention]
[0018]
Embodiment 1
Drawing 1 is a sectional view of the 1st embodiment of the micro mirror structure 100. The structure 100 contains an optical element or the front face 120, the supporting structure 123, and the substrate 140. The supporting structure has attached the optical element 120 to the substrate 140. A substrate contains at least one electrode used in order to draw the element 120 electrostatically. As for the moving element, in the front face, the layer is made from the radiation resistance coating 110. The radiation resistance layer 110 may be reflexibility substantially. Substantially, although it is desirable for reflectance to be larger than 20% as for the reflexible surface, it is not limited to this. This reflectance level is lower in high frequency / low wavelength than it can set to a visible range. Before contacting the front face 120, by making an energy density small, the damage caused with the photon to the surface and the bulk character of the reflected-light study element 120 which were exposed caused by a low fluence and the high-energy-light child decreases. A low fluence characterizes it as the fluence per [lower than the 100 micro joule per square centimeter] one pulse. The mirror element 120 may comprise aluminum. A silicon nitride, silicon, titanium, tantalum, or tungsten may also be included without aluminum or aluminum. The foundation structure of a movable optical element Aluminum, a silicon nitride, silicon, titanium, tantalum, tungsten, or other materials which were mutually used as the layer or were compounded and ** without enough ductility which can fully be deflected by the elastic hysteresis it is considered that is a slight quantity — although material [like] can be comprised, it is not limited to these. A reflecting layer can be attached including aluminum, silver, gold, and a certain reflector for which it was, and it crawled and was suitable from other ones of shoes, although not illustrated individually.
[0019]
The radiation resistance layer 110 Oxide; yttrium or scandium; or magnesium of hafnium, silicon, and aluminum, Fluoride of calcium, a lantern, lithium, molybdenum, sodium and aluminum, neodymium, gadolinium, or aluminum; they may be silicon compound [of molybdenum];, one layer which comprises the carbide of boron again, or two or more layers. For example, 4 to six mutual layers of the oxide of aluminum and silicon may be used. In other embodiments, the layer of many layers, 50, or 100 may be used. Using many layers Angela DEYUPARE, Stephen Jaco Bus & Nor Bert Kaiser, Reference is made in "influence on the quality of optical coating for a substrate face and UV spectral region of membranous granularity", SPIE Vol.3110, and a situation that sets and is different without 509 – 516 pages, and this document has mentioned the system which has 49 layers in 510 pages. N. Keyser, H. you rig, U.B. SHAREMBAGU, B. Anton, U. Keyser, K. Martin, E. Eve, "high damage threshold value aluminum$_2$O$_3$/SiO$_2$ dielectric coating for excimer laser", Even if it sets without Singh solid Phil Mus, No.260, and 86 – 92 pages (1995), reference is made, and this has mentioned the system of 24 layers in 87 pages. A radiation resistance layer may be attached by known adhesion and ion implantation technology. Adhesion technology includes sputtering, CVD, electronic vacuum deposition, laser evaporation and laser, or plasma enhancement oxidation.
[0020]
The reflector of a mirror can be smoothed as mentioned above in advance of adhesion of desirable radiation resistance coating by the surface smoothing technology in which it was suitable from chemical mechanical polishing (CMP) or some of other ones. As for the front face of a movable optical element, it is desirable to have advanced smoothing. This is considered to be useful to make the interaction to an irradiation light child's surface into noninterfering. As for smoothing of the surface of an optical element, it is more desirable that it must be smaller than 2nmRMS (root mean square), and is smaller than 1nmRMS, and it is still more desirable that it is smaller than 0.5nmRMS.
[0021]
Reducing the wavelength of 248 nm or less substantially to the low fluence photon which it has is expected in the loss or damage to reflexible which produces such radiation resistance coating from the addition pulse of a large number which exceed 1 billion. It is expected that it remains while it has been flatter even if the surface has each addition pulse.
[0022]
The embodiment in drawing 1 shows the antireflection coating 130 on the rear face of the above-mentioned mirror element 120, the above-mentioned supporting structure 123, and the above-mentioned substrate 140 located in the bottom containing the one electrode 150 even if small. The antireflection coating 130 The fluoride of magnesium or calcium or silicon and/, or the oxide of aluminum, Or one or more layers of coating for which it was suitable from some of other ones which have quality of acid resistibility in the wavelength used may be comprised. The antireflection coating 130 decreases a reflection of the imitation which may be able to be set under the reflector of the SLM element which may cause degradation of the fidelity of the reflected picture which is generated by the optical element of SLM. Such the quality of acid resistibility of radiation resistance coating can provide the protection to the circuit located in the bottom which may be sensitive to the photon of short wavelength with such high energy.
[0023]

The thickness of radiation resistance coating is usually within the limits of two to 150 nm. It is desirable that it is within the limits of five to 100 nm, and it is more desirable that it is in within the limits which is ten to 50 nm.
[0024]
The thickness of antireflection coating is usually within the limits of 15 to 80 nm. It is desirable that it is within the limits of 15 to 70 nm, and it is more desirable that it is in within the limits which is 20 to 60 nm.
[0025]
If the sectional view in drawing 1 is compared with the isometrical drawing of drawing 9, it is clear that it is not necessary central vertical structure's 123 to have the same installation area as the light modulation structure 120. That is, the torsion hinge 60 may be formed so that it may have the support 50 in one of ends. Much reflexibility and transmission nature geometry can obtain profits from application of this invention, having the various structures for supporting the light modulation structure 120.
[0026]
Embodiment 2
Drawing 2 is a sectional view of the 2nd embodiment of the micro mirror structure 200 of this invention. The above-mentioned structure 200 contains the optical element 220, the supporting structure 223, and the substrate 240. The supporting structure has attached the optical element 220 to the above-mentioned substrate 240. A substrate contains at least one electrode which draws the above-mentioned optical element 220 electrostatically. The mirror element is covered by the radiation resistance coating 210. The above-mentioned coating decreases substantially the influence in the bulk and the surface which are caused to a photon on the reflective element 220 when a low fluence photon is exposed in the wavelength of 248 nm or less.
[0027]
The reflected-light study element 220 may comprise the reflective coating or the substrate for which wavelength was suitable from aluminum or some of other ones. The radiation resistance coating 210 may comprise one or more things of hafnium, aluminum, the oxide of silicon or calcium, magnesium, the fluoride of lithium, or the carbide of boron. Platina ** palladium, a ruthenium, rhodium, a rhenium, osmium, or metal like iridium can be used also as radiation resistance coating. It may be single or a multilayer coating tip may be adhered. The radiation resistance coating 210 may adhere by known ion implantation technology in known adhesion (deposition) and/, or this field. It is activated, and the optical element by which ion implantation was carried out uses a well-known standard annealing procedure for the engineer of this field, and is good also as radiation resistance by an after-placing annealing. The upper surface of the reflected-light study element which is not coated may be smoothed before forming the radiation resistance coating 210.
[0028]
The radiation resistance coating 210 is substantially decreased to low fluence wavelength light of 248 nm or less from the addition exposure which exceeds 1 billion for a luminosity and the wastage rate of contrast. The radiation resistance coating 210 has the loss of equivalent reflexibility to several 1 billion pulses, and makes the resistance to the above-mentioned radiation increase from the range of hundreds of millions pulses to them. Radiation resistance coating protects the surface from chemical and the physical change which are caused with a photon selectively forming the cover which decreases the number of the photons which arrive at a reflector, and by fixing the atom and electron of a reflected-light study element on that occasion.
[0029]
Like drawing 1, the embodiment in drawing 2 is illustrated again so that it may have the antireflection coating 230 on the rear face of the above-mentioned mirror element 220, and at least a part of above-mentioned supporting structure 223, but on the above-mentioned substrate 240 located in the bottom which contains the one electrode 250 even if small, it does not have it. The antireflection coating 230 The fluoride of magnesium or calcium or silicon and/, or the oxide of aluminum, Or one or more layers formed by the adhesion of coating which was suitable from some of other ones which have quality of acid resistibility in the wavelength used may be comprised. The above-mentioned antireflection coating 230 decreases a reflection of the imitation under the reflector of the SLM element which may cause degradation of the fidelity of the reflected picture which is generated by the reflected-light study element of SLM. Such the quality of acid resistibility of coating can provide the protection to the circuit located in the bottom which may be sensitive to the photon of such high energy and short wavelength.
[0030]
Embodiment 3
Drawing 3 shows the 3rd embodiment of the micro mirror structure 300. in this example -- the antireflection coating 330 -- the above -- the substrate 340 which contains the one electrode 350 even if small -- a wrap -- it is illustrated like. The rear face and the above-mentioned supporting structure of the above-mentioned mirror element 320 are not covered with the above-mentioned antireflection coating.
[0031]
Embodiment 4
Drawing 4 shows the 4th embodiment of the micro mirror structure 400. The above-mentioned structure 400 contains the mirror element 420, the supporting structure 423, the substrate 440, and at least one electrode 450 like other embodiments. The mirror element 420 is covered with the radiation resistance coating 410. In this example, antireflection coating is omitted thoroughly.
[0032]
In drawing 1 and the embodiment shown in 2, 3, and 4, it may be thought that a mirror element contains an optical element and a constituent child. Optics and a constituent child may comprise one basic material like the alloy of aluminum or aluminum.
[0033]
Embodiment 5
drawing 5 is based on this invention -- being the further -- others -- the embodiment is shown and the mirror constituent child 520 may be covered by the optical element here on the front face 522, its rear face 521, or its both. The mirror constituent child 520 in this case A silicon nitride, titanium, tantalum, material like tungsten that does not have ductility more, Or material without the ductility for which few deviation hystereses like the compound of material without silicon or similar ductility are shown, or it was suitable from some of something else which does not show a deviation hysteresis may be comprised.
[0034]
The micro mirror structure 500 is dramatically similar with the structure shown in drawing 1. The mirror constituent child 520 may comprise single element composition, or may comprise aluminum, copper, and an alloy like the alloy of silicon. The constituent child 520 may be the accumulated structure containing two or more layers of a different material. The material in the structure which was accumulated as for the account of the upper may be designed make any temporary modification of a mirror into the minimum effectively when temporary modification continues for a long time than the time between pulses.

[0035]
The optical element 522 may be an alloy of aluminum and aluminum, silver, gold, or other suitable arbitrary materials that have high reflectance.
[0036]
The radiation resistance element 510 can be one layer or two or more layers as mentioned above.
[0037]
An aluminum micro mirror may be hardened by boron carbide. Boron carbide may be attached to an aluminum micro mirror by the ion implantation of a boron ion and a carbon ion. The annealing of the micro mirror may be carried out by thermal annealing after placing, for example.
[0038]
Embodiment 6-8
The reference number in drawing 5 is equivalent to the reference number in drawing 1, and the number 100 is exchanged for the number 500. The same rule also as drawing 6-8 is applied, the feature in drawing 6 corresponds to drawing 2, drawing 7 corresponds to drawing 3, and drawing 8 corresponds to drawing 4. The above-mentioned explanation is applied to the feature shown in drawing 6-8.
[0039]
One mode of this invention is a method for improving the resistance to the damage caused by radiation of an optical minute electric machine system (MEMS). MEMS may also contain at least one movable modulation element. The damage to a modulation element may be produced from a low fluence and the addition pulse of the electromagnetic radiation of short wavelength. The low fluence as used in this situation means low energy density. This method includes forming at least one radiation resistance layer on the front-face at least one movable modulation element side. According to this method, in operating wavelength shorter than about 240 nm or it, a radiation resistance layer may be reflexibility substantially. A radiation resistance layer may also contain the oxide of at least one hafnium, aluminum, or silicon. A radiation resistance layer may also contain the fluoride of at least one magnesium, a lantern, or lithium. A radiation resistance layer may also include the combination of an oxide and fluoride. A radiation resistance layer may also contain a placing layer. This layer will be driven in on the front-face a movable modulation element side. Placing may also contain boron and carbon. Placing may be activated. Annealing like heat annealing may be used for activation. One radiation resistance layer or two or more radiation resistance layers may have a thickness of about 30 to 70 nm. It may have a thickness of about 2 nm to 50 nm, or 50 to 100 nm. A movable modulation element may also contain one or more of the materials of aluminum or a silicon nitride, silicon, titanium, tantalum, or tungsten. The material composition to a radiation resistance layer may be the average bulk composition from the upper part of a layer to the lower part of a layer. A reflecting layer may be formed before forming a radiation resistance layer. A reflecting layer may also contain one or more of aluminum, silver, or the gold. A movable modulation element may have the rear-face side, and a method may also include forming one antireflection layer or two or more antireflection layers on the rear-face side of an element further. One antireflection layer or two or more antireflection layers may also contain the fluoride of magnesium or calcium. one antireflection layer or two or more antireflection layer thickness — 15 to 100 nm — or it may be 40 to 60 nm, or 60 to 80 nm again. A movable modulation element may be reflexibility or transmission nature. The transmission nature as used in this situation means a substantially transparent thing to the wavelength of 248 nm or less. A movable modulation element may also contain the oxide of the oxide of silicon and silicon, aluminum, or aluminum. Other modes of this example are carrying out flattening of the front-face side of a movable modulation element, before forming a radiation resistance layer. It may be good root-mean-square surface smoothness, as for the result of flattening, it is desirable that it is better than 1 nm, and it is more desirable than 2 nm that it is better than 0.5 nm over the surface of an element. In this situation, the element may be about 16 microns in width. Flattening may be performed using an abrasive grain of a size smaller than 300 nm like about 70 nm or about 50 nm. The element and mode which are explained here are combinable with various useful combination.
[0040]
The element as the result is manufactured corresponding to the above-mentioned method. One embodiment of this invention is at least one movable modulation element of the optics MEMS containing at least one radiation resistance layer the front-face side and on the front-face side. A radiation resistance layer may be reflexibility substantially to the radiation in wavelength shorter than 248 nm or it. A radiation resistance layer may also contain arbitrary things among composition of being explained here. The surface smoothness characteristic of an element may be explained in a method. A radiation resistance layer may be combined on a support non-movable substrate with one or more antireflection layers formed on the rear face of a movable modulation element, or these both sides.
[0041]
Although this invention is indicated upwards with reference to the desirable embodiment and illustration which were explained in detail, it is understood that these illustration is not what restricts the range of this invention. It is thought that change of technology and the combination which were indicated upwards are easily invented to the engineer of this field. It will be considered that such change and combination are within the limits of this invention and the following claims. The desirable embodiment is described with reference to the movable reflective SLM optical element and the device. To the engineer of this field, MEMS structures other than the reflection SLM like the transmission SLM should also understand that profits can be obtained from the mode of this invention. To the transmission SLMs, a radiation resistance layer may be formed on transmission structure, and it may be chosen so that it may not be reflexibility in essence. For example, an antireflection layer may be formed on the front-face side of transmission structure, or the rear-face side.
[Brief Description of the Drawings]
[0042]
[Drawing 1]It is a sectional view of the 1st embodiment of the MEMS structure of this invention.
[Drawing 2]It is a sectional view of the 2nd embodiment of the MEMS structure of this invention.
[Drawing 3]It is a sectional view of the 3rd embodiment of the MEMS structure of this invention.
[Drawing 4]It is a sectional view of the 4th embodiment of the MEMS structure of this invention.
[Drawing 5]It is a sectional view of the 5th embodiment of the MEMS structure of this invention.
[Drawing 6]It is a sectional view of the 6th embodiment of the MEMS structure of this invention.
[Drawing 7]It is a sectional view of the 7th embodiment of the MEMS structure of this invention.
[Drawing 8]It is a sectional view of the 8th embodiment of the MEMS structure of this invention.
[Drawing 9]It is an isometrical drawing of an example of micro mirror structure.

[Translation done.]

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]
[0042]
[Drawing 1]It is a sectional view of the 1st embodiment of the MEMS structure of this invention.
[Drawing 2]It is a sectional view of the 2nd embodiment of the MEMS structure of this invention.
[Drawing 3]It is a sectional view of the 3rd embodiment of the MEMS structure of this invention.
[Drawing 4]It is a sectional view of the 4th embodiment of the MEMS structure of this invention.
[Drawing 5]It is a sectional view of the 5th embodiment of the MEMS structure of this invention.
[Drawing 6]It is a sectional view of the 6th embodiment of the MEMS structure of this invention.
[Drawing 7]It is a sectional view of the 7th embodiment of the MEMS structure of this invention.
[Drawing 8]It is a sectional view of the 8th embodiment of the MEMS structure of this invention.
[Drawing 9]It is an isometrical drawing of an example of micro mirror structure.

[Translation done.]

DRAWINGS

[Drawing 1]

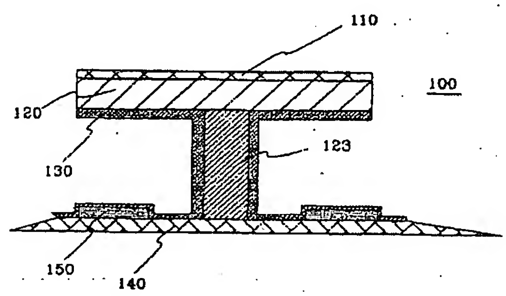

Fig. 1

[Drawing 2]

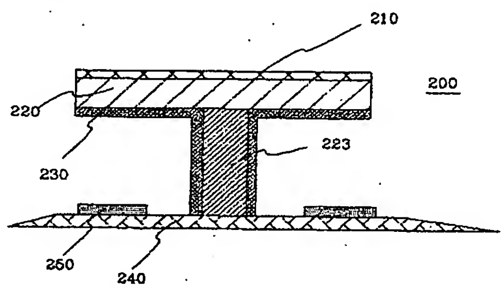

Fig. 2

[Drawing 3]

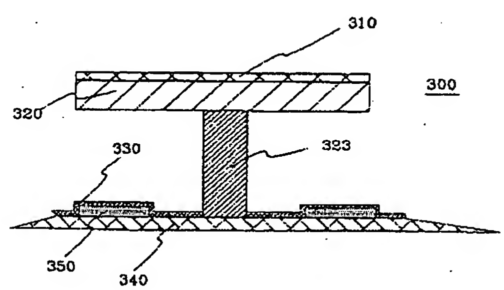

Fig. 3

[Drawing 4]

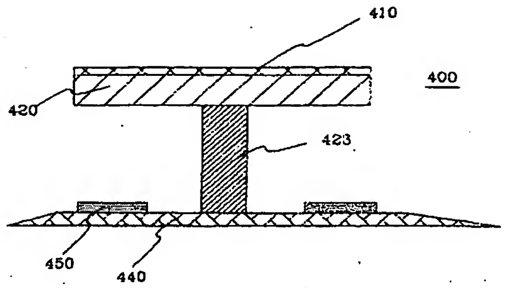

Fig. 4

[Drawing 5]

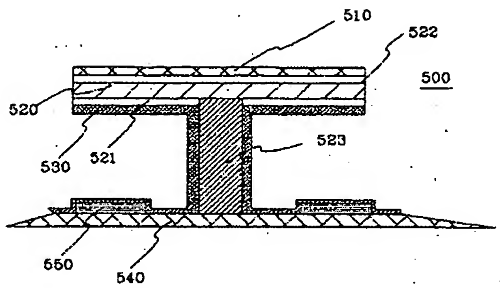

Fig. 5

[Drawing 6]

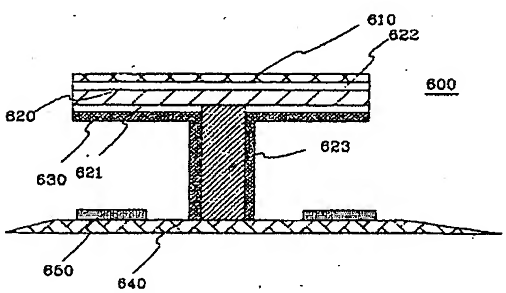

Fig. 6

[Drawing 7]

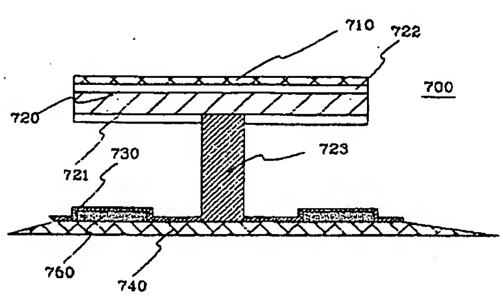

Fig. 7

[Drawing 8]

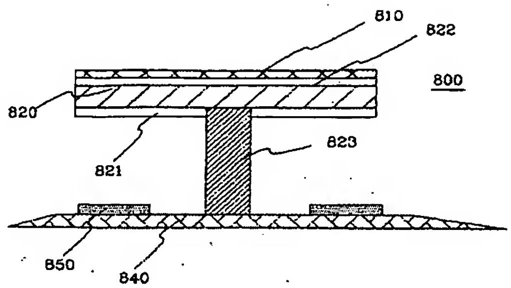

Fig. 8

[Drawing 9]

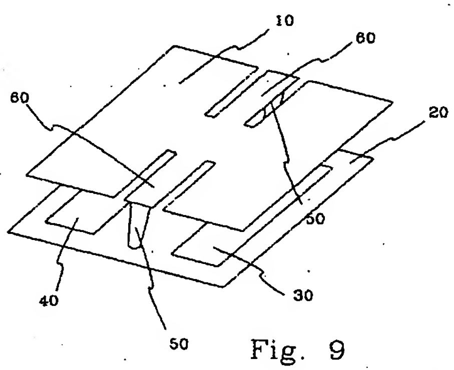

Fig. 9

[Translation done.]

WRITTEN AMENDMENT

[Written Amendment]
[Filing date]Heisei 17(2005) March 9 (2005.3.9)
[Amendment 1]
[Document to be Amended]Claims
[Item(s) to be Amended]Whole sentence
[Method of Amendment]Change
[The contents of amendment]
[Claim(s)]
[Claim 1]
It is how to improve resistance to damage caused by radiation in an optical minute electric machine system (MEMS) containing at least one movable modulation element, and said damage is produced from a low fluence and an addition pulse of electromagnetic radiation of short wavelength,
In operating wavelength including forming at least one radiation resistance layer on the front-face said at least one movable modulation element side in which said radiation resistance layer is shorter than about 248 nm or it, it is reflexibility substantially,
A described method.
[Claim 2]
In a method according to claim 1, said radiation resistance layer, An oxide (Hf_aO_b) of hafnium, fluoride of magnesium (Mg_eF_x), A described method containing at least one of fluoride (La_pF_x) of a lantern, an oxide (aluminum_sO_t) of aluminum, an oxide (Si_yO_x) of silicon, or fluorides (Li_kF_z) of lithium.
[Claim 3]
A described method with which said radiation resistance layer contains an oxide of hafnium, an oxide of aluminum, or an oxide of silicon in a method according to claim 1.
[Claim 4]
A described method with which said radiation resistance layer contains fluoride of magnesium, fluoride of calcium, or fluoride of lithium in a method according to claim 1.
[Claim 5]
A described method which is a said radiation resistance layer placing-layer by the side of a front face of said movable modulation element in a method according to claim 1.
[Claim 6]
A described method with which said placing radiation resistance layer is activated in a method according to claim 5.
[Claim 7]
A described method with which said placing radiation resistance layer comprises placing element boron and carbon in a method according to claim 6.
[Claim 8]
Including being the method according to claim 1 and forming further two or more radiation resistance layers, said two or more radiation resistance layers, a placing layer by which an oxide of hafnium, an oxide of aluminum, an oxide of silicon, fluoride of magnesium, fluoride of calcium, fluoride of lithium or boron, and carbon were activated, and ** — a described method of at least one inside to include.
[Claim 9]
A described method in which said radiation resistance layer has a thickness of about 30 to 70 nm in a method according to claim 1.
[Claim 10]
A described method in which said radiation resistance layer has a thickness of about 2 to 50 nm in a method according to claim 1.
[Claim 11]
A described method in which said radiation resistance layer has a thickness of about 50 to 100 nm in a method according to claim 1.
[Claim 12]
A described method with which said movable modulation element contains aluminum in a method according to claim 1.
[Claim 13]
A described method with which said movable modulation element includes material of one or more of a silicon nitride, silicon, titanium, tantalum, or the tungsten in a method according to claim 1.
[Claim 14]
A described method in which said material composition of on a method according to claim 1 and as opposed to said radiation resistance layer is the average bulk composition from the upper part of said layer to the lower part of said layer.
[Claim 15]
A described method in which said material composition to one with said two or more radiation resistance layers arbitrary in a method according to claim 2 is the average bulk composition from the upper part of said layer to the lower part of said layer.
[Claim 16]

A described method which is the method according to claim 1 and includes forming further a reflecting layer containing one or more of aluminum, silver, and the gold before forming said radiation resistance layer.
[Claim 17]
A described method which said movable modulation element has the rear-face side, and includes forming at least one antireflection layer on said rear-face side further in a method according to claim 1.
[Claim 18]
A described method with which said antireflection layer contains CaF_2 or MgF_2 in a method according to claim 17.
[Claim 19]
A described method with which said antireflection layer contains fluoride of magnesium or calcium in a method according to claim 17.
[Claim 20]
A described method in which said antireflection layer has a thickness of about 15 to 80 nm in a method according to claim 17.
[Claim 21]
A described method in which said antireflection layer has a thickness of about 40 to 60 nm in a method according to claim 17.
[Claim 22]
A described method in which said antireflection layer has a thickness of about 60 to 80 nm in a method according to claim 17.
[Claim 23]
A described method with which said movable modulation element transmits electromagnetic radiation in a method according to claim 1.
[Claim 24]
In a method according to claim 23, said movable modulation element is a transparent described method substantially to wavelength of 248 nm or less.
[Claim 25]
A described method with which said movable modulation element contains an oxide of silicon in a method according to claim 23.
[Claim 26]
A described method with which said radiation resistance layer contains one layer in a method according to claim 23.
[Claim 27]
A described method with which said radiation resistance layer contains two or more layers in a method according to claim 23.
[Claim 28]
A described method with which said radiation resistance layer contains fluoride of magnesium or calcium in a method according to claim 23.
[Claim 29]
A described method in which said radiation resistance element is an oxide of two, aluminum beyond it, or silicon in a method according to claim 23.
[Claim 30]
A described method which is the method according to claim 1 and includes carrying out flattening of said front-face side further before forming said radiation resistance layer.
[Claim 31]
A described method with which said front-face side has good RMS surface smoothness from 2 nm after said flattening in a method according to claim 30.
[Claim 32]
A described method with which said front-face side has good RMS surface smoothness from 1 nm after said flattening in a method according to claim 30.
[Claim 33]
A described method with which said front-face side has good RMS surface smoothness from 0.5 nm after said flattening in a method according to claim 30.
[Claim 34]
A described method which contains CPM which uses an abrasive grain of a size in which said flattening is smaller than 300 nm in a method according to claim 30.
[Claim 35]
A described method with which said flattening contains CPM which uses an abrasive grain with a size of about 70 nm in a method according to claim 30.
[Claim 36]
A described method with which said flattening contains CPM which uses an abrasive grain with a size of about 50 nm in a method according to claim 30.
[Claim 37]
It is at least one movable modulation element of an optical minute electric machine system (MEMS),
The front-face side,
In operating wavelength including at least one radiation resistance layer on said front-face side in which said radiation resistance layer is shorter than about 248 nm or it, it is reflexibility substantially to radiation,
The above-mentioned movable modulation element.
[Claim 38]
The above-mentioned element which is transmission nature substantially in operating wavelength in the element according to claim 37 whose said movable modulation element and said radiation resistance layer are shorter than about 248 nm or it.
[Claim 39]
In the element according to claim 37, said radiation resistance layer, The above-mentioned element containing at least one of a hafnium acid ghost (HfO_2), magnesium fluoride (MgF_2), an aluminum oxide ($aluminum_2O_3$), a silica dioxide (SiO_2), or lithium fluorides (LiF_2).
[Claim 40]
A described method with which said radiation resistance layer contains an oxide of hafnium, an oxide of aluminum, or an oxide of silicon in a method according to claim 37.

[Claim 41]
A described method with which said radiation resistance layer contains fluoride of magnesium, fluoride of calcium, or fluoride of lithium in a method according to claim 37.
[Claim 42]
A described method which is a said radiation resistance layer placing-layer by the side of a front face of said movable modulation element in a method according to claim 37.
[Claim 43]
A described method which is a flat surface where said front-face side has 2 nm or better RMS in a method according to claim 37.
[Claim 44]
It is the element according to claim 37, and is a pan,
The rear-face side of said movable modulation element,
At least one antireflection layer formed on said rear-face side,
******, the above-mentioned element.
[Claim 45]
It is the element according to claim 43, and is a pan,
A non-movable substrate under said movable modulation element which said moving element combines in movable,
At least one antireflection layer formed in said a part of non-movable substrate,
******, the above-mentioned element.

[Translation done.]

CORRECTION OR AMENDMENT

[Kind of official gazette]Correction of published Japanese translations of PCT international publication for patent applications
[Section Type] The 2nd Type of the part VI gate
[Publication date]Heisei 18(2006) August 17 (2006.8.17)

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[Announcement date] Heisei 18(2006) April 20 (2006.4.20)
[Annual volume number] Public presentation / registration gazette 2006-016
[Application number]Application for patent 2004-564602 (P2004-564602)
[Correction summary] A whole sentence is corrected by incorrect ** of a priority date as follows.
[International Patent Classification]

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G02B 1/11 (2006. 01)

B81B 3/00 (2006. 01)
[FI]

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(19)[Publication country]Japan Patent Office (JP)
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(43)[Announcement date] Heisei 18(2006) April 20 (2006.4.20)
(54)[Title of the Invention]High energy, a radiation resistance optical element of low energy density which are used with a minute electric machine element
(51)[International Patent Classification]

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[FI]

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[Request for Examination]Unrequested
[Preliminary examination claim] Tamotsu
[Number of Pages]21
(21)[Application number]Application for patent 2004-564602 (P2004-564602)
(86)(22)[Filing date]Heisei 15(2003) December 19 (2003.12.19)
(85)[Translation Date of submission] Heisei 17(2005) June 30 (2005.6.30)
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(81)[Designated state] AP (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), EA (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), EP (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OA (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG), AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ,

LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM,TN,TR,TT,TZ,UA,UG,UZ,VC,VN,YU,ZA,ZM,ZW
(71)[Applicant]
[Identification Number]504095793
[Name]micro nick Laser Systems AKUCHI — bora — get
[Address]Sweden, TABII, NIITORUPUSUBEGEN 9
(71)[Applicant]
[Identification Number]505250029
[Name]Fraunhofer - Gesellschaft Vine FEDERUNGU Dell ANGE vente ten FORUSHUNGU Ey . FAO.
[Address]Federal Republic of Germany 80686 Munich and alder ZASHUTORASE 27 Tse
(74)[Attorney]
[Identification Number]100066692
[Patent Attorney]
[Name]ASAMURA, Kiyoshi
(74)[Attorney]
[Identification Number]100072040
[Patent Attorney]
[Name]ASAMURA, Hajime
(74)[Attorney]
[Identification Number]100102897
[Patent Attorney]
[Name]IKEDA, Yukihiro
(74)[Attorney]
[Identification Number]100088926
[Patent Attorney]
[Name]NAGANUMA, Teruo
(72)[Inventor(s)]
[Name]Sand SUTOREMU, torr BYORUN
[Address]Sweden, pix bow, and Van Bex Genn 56
(72)[Inventor(s)]
[Name]It is prodigal and they are bottle skiing, Thomas, and Jay.
[Address]United States of America, California, Alamo, and Sydney 230
(72)[Inventor(s)]
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(72)[Inventor(s)]
[Name]Lung Brad, URURIKKU
[Address]Sweden, Melndal, ARUFUHEIDESUGATAN 12
(72)[Inventor(s)]
[Name]KUNASU, Christiane
[Address]The Federal Republic of Germany, Dresden, rhe NITSUERU MUERUVEKU 68
(72)[Inventor(s)]
[Name]Eberhardt, Qus
[Address]The Federal Republic of Germany, MORITSUBURUKU, Ham Walter SUGURUNDO 4
[Theme code (reference)]

2H041

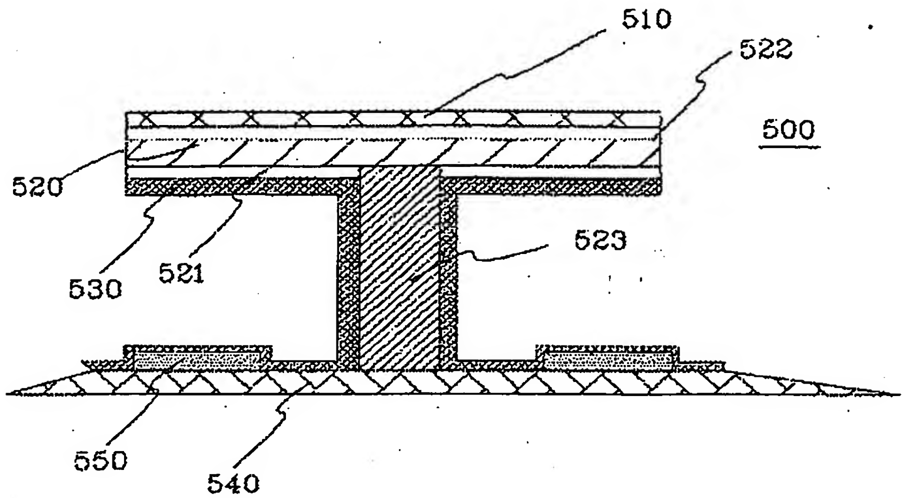
2K009
[F-term (reference)]

2H041 AA14 AB14 AC06 AZ08

2K009 AA02 CC06

(57)

[Abstract]
This invention contains the method and element which improve the radiation resistance of a movable minute machine optical element. . Produce, when the owner pulsed laser energy of an energy density smaller than the 100-micro joule per square centimeter is especially exposed in the wavelength of about 248 nm or less. A radiation resistance layer suitable for decreasing change of the surface in an element and a bulk material is added to a movable minute machine optical element.



[Claim(s)]
[Claim 1]
It is how to improve resistance to damage caused by radiation in an optical minute electric machine system (MEMS) containing at least one movable modulation element, and said damage is produced from a low fluence and an addition pulse of electromagnetic radiation of short wavelength,
At least one radiation resistance layer is formed on the front-face said at least one movable modulation element side,
******, a described method.
[Claim 2]
A described method which is reflexibility substantially in operating wavelength in a method according to claim 1 in which said radiation resistance layer is shorter than about 248 nm or it.
[Claim 3]
In a method according to claim 1, said radiation resistance layer, An oxide (Hf_aO_b) of hafnium, fluoride of magnesium (Mg_eF_x), A described method containing at least one of fluoride (La_pF_x) of a lantern, an oxide (aluminum$_sO_t$) of aluminum, an oxide (Si_yO_x) of silicon, or fluorides (Li_kF_z) of lithium.
[Claim 4]
A described method with which said radiation resistance layer contains an oxide of hafnium, an oxide of aluminum, or an oxide of silicon in a method according to claim 1.
[Claim 5]
A described method with which said radiation resistance layer contains fluoride of magnesium, fluoride of calcium, or fluoride of lithium in a method according to claim 1.
[Claim 6]
A described method which is a said radiation resistance layer placing-layer by the side of a front face of said movable modulation element in a method according to claim 1.
[Claim 7]
A described method with which said placing radiation resistance layer is activated in a method according to claim 6.
[Claim 8]
A described method with which said placing radiation resistance layer comprises placing element boron and carbon in a method according to claim 7.
[Claim 9]
Including being the method according to claim 1 and forming further two or more radiation resistance layers, said two or more radiation resistance layers, a placing layer by which an oxide of hafnium, an oxide of aluminum, an oxide of silicon, fluoride of magnesium, fluoride of calcium, fluoride of lithium or boron, and carbon were activated, and ** -- a described method of at least one inside to include.
[Claim 10]
A described method in which said radiation resistance layer has a thickness of about 30 to 70 nm in a method according to claim 1.
[Claim 11]
A described method in which said radiation resistance layer has a thickness of about 2 to 50 nm in a method according to claim 1.
[Claim 12]
A described method in which said radiation resistance layer has a thickness of about 50 to 100 nm in a method according to claim 1.
[Claim 13]
A described method with which said movable modulation element contains aluminum in a method according to claim 1.
[Claim 14]
A described method with which said movable modulation element includes material of one or more of a silicon nitride, silicon, titanium, tantalum, or the tungsten in a method according to claim 1.
[Claim 15]
A described method in which said material composition of on a method according to claim 1 and as opposed to said radiation resistance layer is the average bulk composition from the upper part of said layer to the lower part of said layer.

[Claim 16]
A described method in which said material composition to one with said two or more radiation resistance layers arbitrary in a method according to claim 3 is the average bulk composition from the upper part of said layer to the lower part of said layer.
[Claim 17]
A described method which is the method according to claim 1 and includes forming further a reflecting layer containing one or more of aluminum, silver, and the gold before forming said radiation resistance layer.
[Claim 18]
A described method which said movable modulation element has the rear-face side, and includes forming at least one antireflection layer on said rear-face side further in a method according to claim 1.
[Claim 19]
A described method with which said antireflection layer contains CaF_2 or MgF_2 in a method according to claim 18.
[Claim 20]
A described method with which said antireflection layer contains fluoride of magnesium or calcium in a method according to claim 18.
[Claim 21]
A described method in which said antireflection layer has a thickness of about 15 to 80 nm in a method according to claim 18.
[Claim 22]
A described method in which said antireflection layer has a thickness of about 40 to 60 nm in a method according to claim 18.
[Claim 23]
A described method in which said antireflection layer has a thickness of about 60 to 80 nm in a method according to claim 18.
[Claim 24]
A described method with which said movable modulation element transmits electromagnetic radiation in a method according to claim 1.
[Claim 25]
In a method according to claim 24, said movable modulation element is a transparent described method substantially to wavelength of 248 nm or less.
[Claim 26]
A described method with which said movable modulation element contains an oxide of silicon in a method according to claim 24.
[Claim 27]
A described method with which said radiation resistance layer contains one layer in a method according to claim 24.
[Claim 28]
A described method with which said radiation resistance layer contains two or more layers in a method according to claim 24.
[Claim 29]
A described method with which said radiation resistance layer contains fluoride of magnesium or calcium in a method according to claim 24.
[Claim 30]
A described method in which said radiation resistance element is an oxide of two, aluminum beyond it, or silicon in a method according to claim 24.
[Claim 31]
A described method which is the method according to claim 1 and includes carrying out flattening of said front-face side further before forming said radiation resistance layer.
[Claim 32]
A described method with which said front-face side has good RMS surface smoothness from 2 nm after said flattening in a method according to claim 31.
[Claim 33]
A described method with which said front-face side has good RMS surface smoothness from 1 nm after said flattening in a method according to claim 31.
[Claim 34]
A described method with which said front-face side has good RMS surface smoothness from 0.5 nm after said flattening in a method according to claim 31.
[Claim 35]
A described method which contains CPM which uses an abrasive grain of a size in which said flattening is smaller than 300 nm in a method according to claim 31.
[Claim 36]
A described method with which said flattening contains CPM which uses an abrasive grain with a size of about 70 nm in a method according to claim 31.
[Claim 37]
A described method with which said flattening contains CPM which uses an abrasive grain with a size of about 50 nm in a method according to claim 31.
[Claim 38]
It is at least one movable modulation element of an optical minute electric machine system (MEMS),
The front-face side,
At least one radiation resistance layer on said front-face side,
******, the above-mentioned movable modulation element.
[Claim 39]
The above-mentioned element which is reflexibility substantially to radiation in operating wavelength in the element according to claim 38 in which said radiation resistance layer is shorter than about 248 nm or it.
[Claim 40]
The above-mentioned element which is transmission nature substantially in operating wavelength in the element according to claim 38 whose said movable modulation element and said radiation resistance layer are shorter than about 248 nm or it.
[Claim 41]
In the element according to claim 38, said radiation resistance layer, The above-mentioned element containing at least one of a

hafnium acid ghost (HfO_2), magnesium fluoride (MgF_2), an aluminum oxide (aluminum$_2O_3$), a silica dioxide (SiO_2), or lithium fluorides (LiF_2).
[Claim 42]
A described method with which said radiation resistance layer contains an oxide of hafnium, an oxide of aluminum, or an oxide of silicon in a method according to claim 38.
[Claim 43]
A described method with which said radiation resistance layer contains fluoride of magnesium, fluoride of calcium, or fluoride of lithium in a method according to claim 38.
[Claim 44]
A described method which is a said radiation resistance layer placing-layer by the side of a front face of said movable modulation element in a method according to claim 38.
[Claim 45]
A described method which is a flat surface where said front-face side has 2 nm or better RMS in a method according to claim 38.
[Claim 46]
It is the element according to claim 38, and is a pan,
The rear-face side of said movable modulation element,
At least one antireflection layer formed on said rear-face side,
******, the above-mentioned element.
[Claim 47]
It is the element according to claim 45, and is a pan,
A non-movable substrate under said movable modulation element which said moving element combines in movable,
At least one antireflection layer formed in said a part of non-movable substrate,
******, the above-mentioned element.
[Detailed Description of the Invention]
[Field of the Invention]
[0001]
(Field of invention)
This invention contains the method and element which improve the radiation resistance of a movable minute machine optical element. . Produce, when the owner pulsed laser energy of an energy density smaller than the 100-micro joule per square centimeter is especially exposed in the wavelength of about 248 nm or less. A radiation resistance layer suitable for decreasing change of the surface in an element and a bulk material is added to a movable minute machine optical element.
[Background of the Invention]
[0002]
(The background of invention)
The optical minute electric machine system (MEMS) or the spatial-light-modulation machine (SLMs) is used in a movie, a presentation projector, and television, in order to generate the image for a televiewer today. A pattern usually appears on the wide range surface like a projection screen or a viewing plate. In such applications, visible wavelength light (400 to 800 nm) is used. MEMS is used again as a switch which turns the beam of light to other optical courses from one optical course. In switching application, normal use of not the ultraviolet radiation that is shorter wavelength but the light of a visible wavelength is carried out.
[0003]
this invention person and their coworker applied SLMs to the micro lithography process included in semiconductor device manufacture recently. SLMs is more detailed, smaller, and it is used in order to generate the picture packed more to high density. In order to describe the picture packed small and with high density, it is required to use a light of short wavelength shorter than the inside of an ultraviolet spectrum or it. Electrostatic activity-ization is used in order to deflect a micro mirror. In order to generate power, it is generated between the electrodes whose voltage is two. One electrode is static and other electrodes are attached to an actuator like a movable micro mirror, for example. For example, SLM which has an array of an actuator used in a mask writing tool or a chip fabrication tool, It is loaded with a specific pattern, and an actuator is in the state or the state where an address is not carried out by which the address was carried out here, when relaying or transmitting the beam of electromagnetic radiation on a manufactured product. The beam of this relayed electromagnetic radiation contains the stamp of the pattern which should be printed on the above-mentioned manufactured product. This pattern may be the subset of a pattern or the perfect pattern which should be printed on a mask or a chip, respectively.
[Description of the Invention]
[Problem to be solved by the invention]
[0004]
Therefore, the opportunity to develop the method and element which are fitted so that SLMs may be used with short wavelength arose, having understood the problem which uses SLMs with the light of short wavelength containing wavelength shorter than about 248 nm or it, and prolonging the usefulness and the life of a MEMS element effectively.
[Means for solving problem]
[0005]
(Outline of invention)
This invention contains the method and element which improve the radiation resistance of a movable minute machine optical element. . Produce, when the owner pulsed laser energy of an energy density smaller than the 100-micro joule per square centimeter is especially exposed in the wavelength of about 248 nm or less. A radiation resistance layer suitable for decreasing change of the surface in an element and a bulk material is added to a movable minute machine optical element.
[0006]
(DETAILED DESCRIPTION)
The following detailed explanation is given with reference to drawing 1-9. A desirable embodiment is described in order to indicate the technology of this invention, and it does not restrict the range of the claim defined here. Various equivalent change will be recognized on the occasion of the following explanation by the engineer of this field.
[0007]

The micro lithography SLMs uses the array of a very small precise movable optical modulator, or an optical element like a mirror. A reflected-light study element may be tens of microns from several microns at one side. The SLM array containing such two or more elements can be from a thing smaller than one centimeter on one side even to tens centimeters in one side. The thickness of an optical element may be the thickness of 1 - 2 microns, or 350 to 700 nm, or may be more thinly [than this] thick. Desirable surface smoothness (buckling of the mountain of a single reflective element to a valley) may be precise about four to ten nm over 16 microns, and may be more precise. The both sides of surface surface smoothness and mechanical stability (the resistance to an edge curl is included) may be required. The lives with a desirable element may be 10 billion or 100 billion pulses from 1 of radiation, and many mechanical deflections. It is because an element creates a desirable micro lithography pattern, so it is adjusted.

[0008]

As compared with SLMs used in order to generate a picture for a televiewer, the micro lithography SLMs uses light of short wavelength rather than having energy per higher photon. A photon of higher energy has high capability rather than changing materially the surface of an optical element, and a physicochemical quality of bulk. It is observed that a high-energy-light child may change an optical property of an optical element in light of short wavelength between development. Generally, a net change per [in character of a reflector in a fixed fluence] photon is in inverse proportion to wavelength of exposure electromagnetic radiation. Generally, change per [in the surface of an optical element and/, or bulk character] photon is so larger that wavelength of electromagnetic radiation is shorter. Change as a result in bulk of an optical element and character of material is irreversible, and cumulative. Change in character of a micro lithography SLMs optical element is desirably irreversible. It is because the quality of a picture which change decreased fidelity, therefore was generated is lowered.

[0009]

A reflected-light study element is formed from a desirable material of high reflectance like aluminum. In a larger pulse ratio than 500 Hz and wavelength of 248 nm or less, an exposure high-energy-light child who has a pulse is reflected from the surface of a movable optical element in an energy density smaller than the 100-micro joule per square centimeter. A photon which collides may affect the surface and bulk character of an optical element mutually.

[0010]

Use of the reflection SLM is not restricted to using such SLM for laser pattern generation. It has intention of the range of a claim so that movable and static, other reflections, and transmission optical element out of use of such technology for the pattern generation based on the laser in an energy density and wavelength which are specified here may be included. Although there are the photonic switch and MEMS shutter array for a scanning mirror and communication as an example, it is not limited to these.

[0011]

It depends on the surface and the bulk character of an optical element for the type of change which can be predicted heavily. When electric conduction, an insulation, and the charge of half-guide members are exposed by the light of the same wavelength and a fluence, reactions differ. Change caused with the photon in the bulk and surface properties of an optical element can be measured directly or indirectly. The material change to a mirror can measure quantity directly by the granularity of hardness, chemical composition, and the surface, the loss of material, the change in thickness, or change in the form of an optical element. The change in the optical property of a mirror can measure quality through the change in reflectance, regular reflectance or non-regular reflectance, a luminosity, or contrast.

[0012]

It is observed that the regist-patterning processing used in order to define the optical element of SLM leaves a residual substance after that so that exposure by environment may be so. A resist process or residual carbon from other sources is observed on the surface of an optical element. Sample structure (what is called a sample with a mirror) contained 350-nm-thick aluminum / magnesium / silicon alloy film on photoresist. The annealing of such sample structures was carried out in 160 ** for 12 hours. What is called structure "processed" was exposed by 90 million of a 248-nm laser beam, 2.5 mJ/cm^2, and the 25-ns pulse in 500 Hz. Other sample structures (what is called a mirror-less sample) had 1000-nm-thick aluminum / magnesium / silicon alloy film without annealing on the single crystal silicon substrate. Some mirror-less samples were processed when low energy density and a high energy laser pulse were exposed. Sample structure was analyzed.

[0013]

In two monolayers of the surface upper part, analysis of the sample showed existence of high carbon relatively. Carbonaceous content was decreasing substantially in about 9 nm inside from the surface. The layer of the aluminum oxide seemed to have mixed with carbon. The particle of the alloy was observed in the surface and considered to be a by-product of sputtering adhesion so that it might be predicted. The particle appeared in the size of the order of 20 to 25 nm. In some processed samples, the particle of the alloy was emitted from the surface, and it was removed finely, and seemed to leave the surface which leaves without completely moving, without changing an adjoining particle, and includes a hole 20 - 30 nanometers deep and which is not even. Desorption of the particle from the surface An H. helluva alder, L. WIDOMAN, and H.S. Kim, "The relevance to the photophysical processing and atomic layer processing in a low fluence UV laser material interaction", It is in agreement with an experimental result without advanced MATERIARUSU Fau optics and electronics, Vol.2, 31 - 42 pages, and the relation to this invention of 40 (1993).

[0014]

The surface hardness of an unsettled structure was also measured with finishing [processing]. When the result analyzed as the power applied by the hysterics TIRON try boss Co-op TM analyzer using AFM was combined, it was thought that the surface of the processed sample was harder than the surface which resists by osmosis by analysis investigation, therefore is not processed. The film considered that the TEM picture of the processed sample with a mirror is the non-same quality physicochemically, and is mixing of aluminum and oxygen with much carbon, magnesium, and silicon was shown. It was surmised that the loss of material (oxygen and particle) and the combination of strengthening of surface hardness were connected with the curve of five to 20 nm observed covering the element face with a width of 16 microns of mirror structure after processing.

[0015]

In accordance with these observation to these observation, the method for processing of the optics MEMS of the schedule [in / about 248 nm] exposed by wavelength shorter than it was developed. Before flattening buffing removes a mirror from the resist located under mirror structure, it may be applied to a mirror, and more generally, it may be applied to the optical MEMS structure of the schedule exposed by short wavelength. As for CMP buffing, in order to make surface granularity small, it is desirable to use a very small abrasive grain. Buffing may be adopted so that fully for removing a particle and smoothing from the surface of

the optics MEMS. It is thought that a particle has the change and the relation after the exposure to the surface and the bulk character of a reflected-light study element. Buffing may be adopted so that fully for removing a particle from the surface of a mirror. It is expected that the slurry based on suitable pH and viscosity, and the other silica that sets and has a particle with a size of 50 or 70 nm is helpful. More generally 300 nm or a smaller abrasive grain may be helpful for the size of particles. Other slurries which use different abrasive soap may often be equally helpful. being developed by the ACSI group of ATMI and Inc. -- brand-name Plana Kem, OS, and a series oxer -- ide -- the slurry currently sold in the name of the SMP slurry has a desirable small grain size. Flattening composition for the structure of these slurries to remove US,5,993,685,B and a metal membrane (November 30, 1999). It is thought that it is based on the research explained to the flattening composition and the method (November 27, 2001) for removing the flattening composition (July 31, 2001) for removing No. 6,267,909 and a metal membrane and No. 6,322,600, and an internal layer dielectric film. Buffing which removes about 5-30, 5-20, 5-10, 10-20, 20-30, the range containing 50 to 100 nm, 5, 10, 20, 30 and 50, 100 nm, or the material not more than it by composition of the optical MEMS surface may be performed. The marginal size of buffing changes with surface configurations. Surface granularity can be observed and measured using an atomic force microscope.

[0016]

Drawing 9 shows the embodiment of the movable microoptics element. A movable optical element may be Motoko Kagami in a spatial-light-modulation machine (SLM) array. This mirror lets the range of a deflecting angle pass, or may be deflected by the binary number maximum or zero deviation. Motoko Kagami's deviation may be linearity or non-linearity as a function of an input signal.

[0017]

In drawing 9, generally the movable optical element 10 is a rectangle, and is supported on 1 set of torsion hinges 60 along with one of omitted portions. Movable optical elements may be arbitrary forms, for example, may be a polygon, and circular or an ellipse form. The above-mentioned hinge is supported by the support element 50. The movable minute element 10, the torsion hinge 60, and the support element may comprise the same material that is aluminum or a different material, for example. The substrate 20 contains the electric conduction electrodes 30 and 40. The electrodes 20 and 30 are connected to the circuit (not shown) made in the substrate 20. If potential difference is applied between one and the above-mentioned optical element of an electrode, electrostatic force will be accumulated and, thereby, it will be electrostatically drawn by the above-mentioned movable optical element (it deviates).

[Best Mode of Carrying Out the Invention]

[0018]

Embodiment 1

Drawing 1 is a sectional view of the 1st embodiment of the micro mirror structure 100. The structure 100 contains an optical element or the front face 120, the supporting structure 123, and the substrate 140. The supporting structure has attached the optical element 120 to the substrate 140. A substrate contains at least one electrode used in order to draw the element 120 electrostatically. As for the moving element, in the front face, the layer is made from the radiation resistance coating 110. The radiation resistance layer 110 may be reflexibility substantially. Substantially, although it is desirable for reflectance to be larger than 20% as for the reflexible surface, it is not limited to this. This reflectance level is lower in high frequency / low wavelength than it can set to a visible range. Before contacting the front face 120, by making an energy density small, the damage caused with the photon to the surface and the bulk character of the reflected-light study element 120 which were exposed caused by a low fluence and the high-energy-light child decreases. A low fluence characterizes it as the fluence per [lower than the 100 micro joule per square centimeter] one pulse. The mirror element 120 may comprise aluminum. A silicon nitride, silicon, titanium, tantalum, or tungsten may also be included without aluminum or aluminum. The foundation structure of a movable optical element Aluminum, a silicon nitride, silicon, titanium, tantalum, tungsten, or other materials which were mutually used as the layer or were compounded and ** without enough ductility which can fully be deflected by the elastic hysteresis it is considered that is a slight quantity -- although material [like] can be comprised, it is not limited to these. A reflecting layer can be attached including aluminum, silver, gold, and a certain reflector for which it was, and it crawled and was suitable from other ones of shoes, although not illustrated individually.

[0019]

The radiation resistance layer 110 Oxide; yttrium or scandium; or magnesium of hafnium, silicon, and aluminum, Fluoride of calcium, a lantern, lithium, molybdenum, sodium and aluminum, neodymium, gadolinium, or aluminum; they may be silicon compound [of molybdenum];, one layer which comprises the carbide of boron again, or two or more layers. For example, 4 to six mutual layers of the oxide of aluminum and silicon may be used. In other embodiments, the layer of many layers, 50, or 100 may be used. Using many layers Angela DEYUPARE, Stephen Jaco Bus & Nor Bert Kaiser, Reference is made in "influence on the quality of optical coating for a substrate face and UV spectral region of membranous granularity", SPIE Vol.3110, and a situation that sets and is different without 509 - 516 pages, and this document has mentioned the system which has 49 layers in 510 pages. N. Keyser, H. you rig, U.B. SHAREMBAGU, B. Anton, U. Keyser, K. Martin, E. Eve, "high damage threshold value (aluminum$_2$O$_3$/SiO$_2$ dielectric coating for excimer laser", Even if it sets without Singh solid Phil Mus, No.260, and 86 - 92 pages (1995), reference is made, and this has mentioned the system of 24 layers in 87 pages. A radiation resistance layer may be attached by known adhesion and ion implantation technology. Adhesion technology includes sputtering, CVD, electronic vacuum deposition, laser evaporation and laser, or plasma enhancement oxidation.

[0020]

The reflector of a mirror can be smoothed as mentioned above in advance of adhesion of desirable radiation resistance coating by the surface smoothing technology in which it was suitable from chemical mechanical polishing (CMP) or some of other ones. As for the front face of a movable optical element, it is desirable to have advanced smoothing. This is considered to be useful to make the interaction to an irradiation light child's surface into noninterfering. As for smoothing of the surface of an optical element, it is more desirable that it must be smaller than 2nmRMS (root mean square), and is smaller than 1nmRMS, and it is still more desirable that it is smaller than 0.5nmRMS.

[0021]

Reducing the wavelength of 248 nm or less substantially to the low fluence photon which it has is expected in the loss or damage to reflexible which produces such radiation resistance coating from the addition pulse of a large number which exceed 1 billion. It is expected that it remains while it has been flatter even if the surface has each addition pulse.

[0022]

The embodiment in drawing 1 shows the antireflection coating 130 on the rear face of the above-mentioned mirror element 120,

the above-mentioned supporting structure 123, and the above-mentioned substrate 140 located in the bottom containing the one electrode 150 even if small. The antireflection coating 130 The fluoride of magnesium or calcium or silicon and/, or the oxide of aluminum, Or one or more layers of coating for which it was suitable from some of other ones which have quality of acid resistibility in the wavelength used may be comprised. The antireflection coating 130 decreases a reflection of the imitation which may be able to be set under the reflector of the SLM element which may cause degradation of the fidelity of the reflected picture which is generated by the optical element of SLM. Such the quality of acid resistibility of radiation resistance coating can provide the protection to the circuit located in the bottom which may be sensitive to the photon of short wavelength with such high energy.

[0023]

The thickness of radiation resistance coating is usually within the limits of two to 150 nm. It is desirable that it is within the limits of five to 100 nm, and it is more desirable that it is in within the limits which is ten to 50 nm.

[0024]

The thickness of antireflection coating is usually within the limits of 15 to 80 nm. It is desirable that it is within the limits of 15 to 70 nm, and it is more desirable that it is in within the limits which is 20 to 60 nm.

[0025]

If the sectional view in drawing 1 is compared with the isometrical drawing of drawing 9, it is clear that it is not necessary central vertical structure's 123 to have the same installation area as the light modulation structure 120. That is, the torsion hinge 60 may be formed so that it may have the support 50 in one of ends. Much reflexibility and transmission nature geometry can obtain profits from application of this invention, having the various structures for supporting the light modulation structure 120.

[0026]

Embodiment 2

Drawing 2 is a sectional view of the 2nd embodiment of the micro mirror structure 200 of this invention. The above-mentioned structure 200 contains the optical element 220, the supporting structure 223, and the substrate 240. The supporting structure has attached the optical element 220 to the above-mentioned substrate 240. A substrate contains at least one electrode which draws the above-mentioned optical element 220 electrostatically. The mirror element is covered by the radiation resistance coating 210. The above-mentioned coating decreases substantially the influence in the bulk and the surface which are caused to a photon on the reflective element 220 when a low fluence photon is exposed in the wavelength of 248 nm or less.

[0027]

The reflected-light study element 220 may comprise the reflective coating or the substrate for which wavelength was suitable from aluminum or some of other ones. The radiation resistance coating 210 may comprise one or more things of hafnium, aluminum, the oxide of silicon or calcium, magnesium, the fluoride of lithium, or the carbide of boron. Platina ** palladium, a ruthenium, rhodium, a rhenium, osmium, or metal like iridium can be used also as radiation resistance coating. It may be single or a multilayer coating tip may be adhered. The radiation resistance coating 210 may adhere by known ion implantation technology in known adhesion (deposition) and/, or this field. It is activated, and the optical element by which ion implantation was carried out uses a well-known standard annealing procedure for the engineer of this field, and is good also as radiation resistance by an after-placing annealing. The upper surface of the reflected-light study element which is not coated may be smoothed before forming the radiation resistance coating 210.

[0028]

The radiation resistance coating 210 is substantially decreased to low fluence wavelength light of 248 nm or less from the addition exposure which exceeds 1 billion for a luminosity and the wastage rate of contrast. The radiation resistance coating 210 has the loss of equivalent reflexibility to several 1 billion pulses, and makes the resistance to the above-mentioned radiation increase from the range of hundreds of millions pulses to them. Radiation resistance coating protects the surface from chemical and the physical change which are caused with a photon selectively forming the cover which decreases the number of the photons which arrive at a reflector, and by fixing the atom and electron of a reflected-light study element on that occasion.

[0029]

Like drawing 1, the embodiment in drawing 2 is illustrated again so that it may have the antireflection coating 230 on the rear face of the above-mentioned mirror element 220, and at least a part of above-mentioned supporting structure 223, but on the above-mentioned substrate 240 located in the bottom which contains the one electrode 250 even if small, it does not have it. The antireflection coating 230 The fluoride of magnesium or calcium or silicon and/, or the oxide of aluminum, Or one or more layers formed by the adhesion of coating which was suitable from some of other ones which have quality of acid resistibility in the wavelength used may be comprised. The above-mentioned antireflection coating 230 decreases a reflection of the imitation under the reflector of the SLM element which may cause degradation of the fidelity of the reflected picture which is generated by the reflected-light study element of SLM. Such the quality of acid resistibility of coating can provide the protection to the circuit located in the bottom which may be sensitive to the photon of such high energy and short wavelength.

[0030]

Embodiment 3

Drawing 3 shows the 3rd embodiment of the micro mirror structure 300. in this example -- the antireflection coating 330 -- the above -- the substrate 340 which contains the one electrode 350 even if small -- a wrap -- it is illustrated like. The rear face and the above-mentioned supporting structure of the above-mentioned mirror element 320 are not covered with the above-mentioned antireflection coating.

[0031]

Embodiment 4

Drawing 4 shows the 4th embodiment of the micro mirror structure 400. The above-mentioned structure 400 contains the mirror element 420, the supporting structure 423, the substrate 440, and at least one electrode 450 like other embodiments. The mirror element 420 is covered with the radiation resistance coating 410. In this example, antireflection coating is omitted thoroughly.

[0032]

In drawing 1 and the embodiment shown in 2, 3, and 4, it may be thought that a mirror element contains an optical element and a constituent child. Optics and a constituent child may comprise one basic material like the alloy of aluminum or aluminum.

[0033]

Embodiment 5

drawing 5 is based on this invention -- being the further -- others -- the embodiment is shown and the mirror constituent child 520 may be covered by the optical element here on the front face 522, its rear face 521, or its both. The mirror constituent child

520 in this case A silicon nitride, titanium, tantalum, material like tungsten that does not have ductility more, Or material without the ductility for which few deviation hystereses like the compound of material without silicon or similar ductility are shown, or it was suitable from some of something else which does not show a deviation hysteresis may be comprised.

[0034]

The micro mirror structure 500 is dramatically similar with the structure shown in drawing 1. The mirror constituent child 520 may comprise single element composition, or may comprise aluminum, copper, and an alloy like the alloy of silicon. The constituent child 520 may be the accumulated structure containing two or more layers of a different material. The material in the structure which was accumulated as for the account of the upper may be designed make any temporary modification of a mirror into the minimum effectively when temporary modification continues for a long time than the time between pulses.

[0035]

The optical element 522 may be an alloy of aluminum and aluminum, silver, gold, or other suitable arbitrary materials that have high reflectance.

[0036]

The radiation resistance element 510 can be one layer or two or more layers as mentioned above.

[0037]

An aluminum micro mirror may be hardened by boron carbide. Boron carbide may be attached to an aluminum micro mirror by the ion implantation of a boron ion and a carbon ion. The annealing of the micro mirror may be carried out by thermal annealing after placing, for example.

[0038]

Embodiment 6-8

The reference number in drawing 5 is equivalent to the reference number in drawing 1, and the number 100 is exchanged for the number 500. The same rule also as drawing 6-8 is applied, the feature in drawing 6 corresponds to drawing 2, drawing 7 corresponds to drawing 3, and drawing 8 corresponds to drawing 4. The above-mentioned explanation is applied to the feature shown in drawing 6-8.

[0039]

One mode of this invention is a method for improving the resistance to the damage caused by radiation of an optical minute electric machine system (MEMS). MEMS may also contain at least one movable modulation element. The damage to a modulation element may be produced from a low fluence and the addition pulse of the electromagnetic radiation of short wavelength. The low fluence as used in this situation means low energy density. This method includes forming at least one radiation resistance layer on the front-face at least one movable modulation element side. According to this method, in operating wavelength shorter than about 240 nm or it, a radiation resistance layer may be reflexibility substantially. A radiation resistance layer may also contain the oxide of at least one hafnium, aluminum, or silicon. A radiation resistance layer may also contain the fluoride of at least one magnesium, a lantern, or lithium. A radiation resistance layer may also include the combination of an oxide and fluoride. A radiation resistance layer may also contain a placing layer. This layer will be driven in on the front-face a movable modulation element side. Placing may also contain boron and carbon. Placing may be activated. Annealing like heat annealing may be used for activation. One radiation resistance layer or two or more radiation resistance layers may have a thickness of about 30 to 70 nm. It may have a thickness of about 2 nm to 50 nm, or 50 to 100 nm. A movable modulation element may also contain one or more of the materials of aluminum or a silicon nitride, silicon, titanium, tantalum, or tungsten. The material composition to a radiation resistance layer may be the average bulk composition from the upper part of a layer to the lower part of a layer. A reflecting layer may be formed before forming a radiation resistance layer. A reflecting layer may also contain one or more of aluminum, silver, or the gold. A movable modulation element may have the rear-face side, and a method may also include forming one antireflection layer or two or more antireflection layers on the rear-face side of an element further. One antireflection layer or two or more antireflection layers may also contain the fluoride of magnesium or calcium. one antireflection layer or two or more antireflection layer thickness — 15 to 100 nm — or it may be 40 to 60 nm, or 60 to 80 nm again. A movable modulation element may be reflexibility or transmission nature. The transmission nature as used in this situation means a substantially transparent thing to the wavelength of 248 nm or less. A movable modulation element may also contain the oxide of the oxide of silicon and silicon, aluminum, or aluminum. Other modes of this example are carrying out flattening of the front-face side of a movable modulation element, before forming a radiation resistance layer. It may be good root-mean-square surface smoothness, as for the result of flattening, it is desirable that it is better than 1 nm, and it is more desirable than 2 nm that it is better than 0.5 nm over the surface of an element. In this situation, the element may be about 16 microns in width. Flattening may be performed using an abrasive grain of a size smaller than 300 nm like about 70 nm or about 50 nm. The element and mode which are explained here are combinable with various useful combination.

[0040]

The element as the result is manufactured corresponding to the above-mentioned method. One embodiment of this invention is at least one movable modulation element of the optics MEMS containing at least one radiation resistance layer the front-face side and on the front-face side. A radiation resistance layer may be reflexibility substantially to the radiation in wavelength shorter than 248 nm or it. A radiation resistance layer may also contain arbitrary things among composition of being explained here. The surface smoothness characteristic of an element may be explained in a method. A radiation resistance layer may be combined on a support non-movable substrate with one or more antireflection layers formed on the rear face of a movable modulation element, or these both sides.

[0041]

Although this invention is indicated upwards with reference to the desirable embodiment and illustration which were explained in detail, it is understood that these illustration is not what restricts the range of this invention. It is thought that change of technology and the combination which were indicated upwards are easily invented to the engineer of this field. It will be considered that such change and combination are within the limits of this invention and the following claims. The desirable embodiment is described with reference to the movable reflective SLM optical element and the device. To the engineer of this field, MEMS structures other than the reflection SLM like the transmission SLM should also understand that profits can be obtained from the mode of this invention. To the transmission SLMs, a radiation resistance layer may be formed on transmission structure, and it may be chosen so that it may not be reflexibility in essence. For example, an antireflection layer may be formed on the front-face side of transmission structure, or the rear-face side.

[Brief Description of the Drawings]

[0042]

[Drawing 1]It is a sectional view of the 1st embodiment of the MEMS structure of this invention.
[Drawing 2]It is a sectional view of the 2nd embodiment of the MEMS structure of this invention.
[Drawing 3]It is a sectional view of the 3rd embodiment of the MEMS structure of this invention.
[Drawing 4]It is a sectional view of the 4th embodiment of the MEMS structure of this invention.
[Drawing 5]It is a sectional view of the 5th embodiment of the MEMS structure of this invention.
[Drawing 6]It is a sectional view of the 6th embodiment of the MEMS structure of this invention.
[Drawing 7]It is a sectional view of the 7th embodiment of the MEMS structure of this invention.
[Drawing 8]It is a sectional view of the 8th embodiment of the MEMS structure of this invention.
[Drawing 9]It is an isometrical drawing of an example of micro mirror structure.

[Drawing 1]

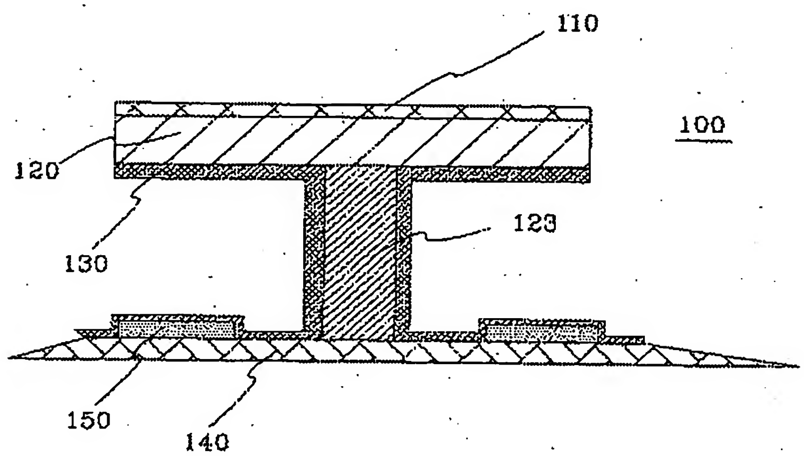


Fig. 1

[Drawing 2]

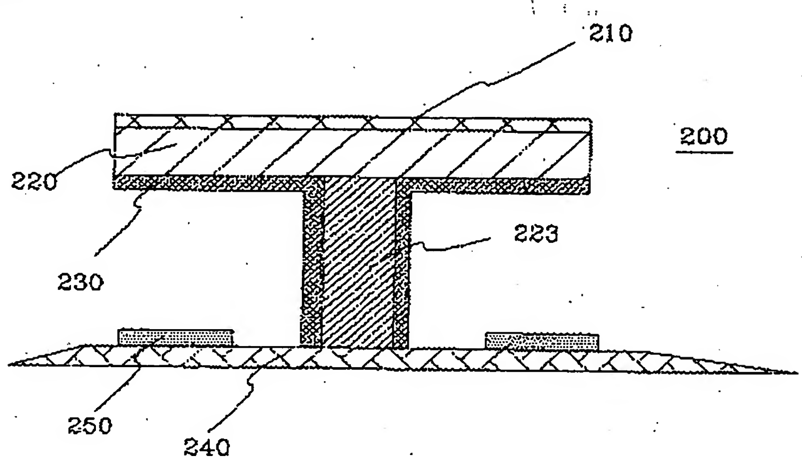


Fig. 2

[Drawing 3]

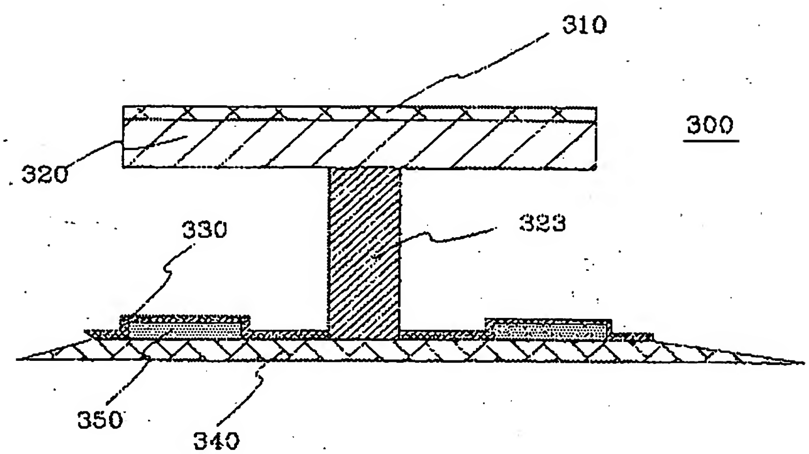


Fig. 3

[Drawing 4]

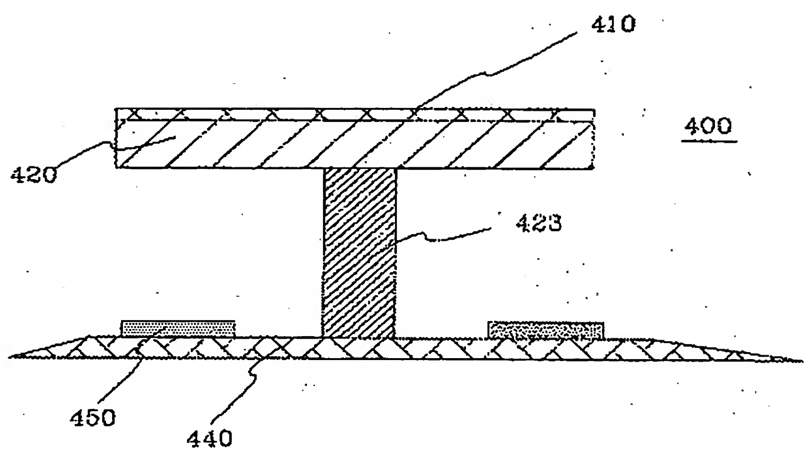


Fig. 4

[Drawing 5]

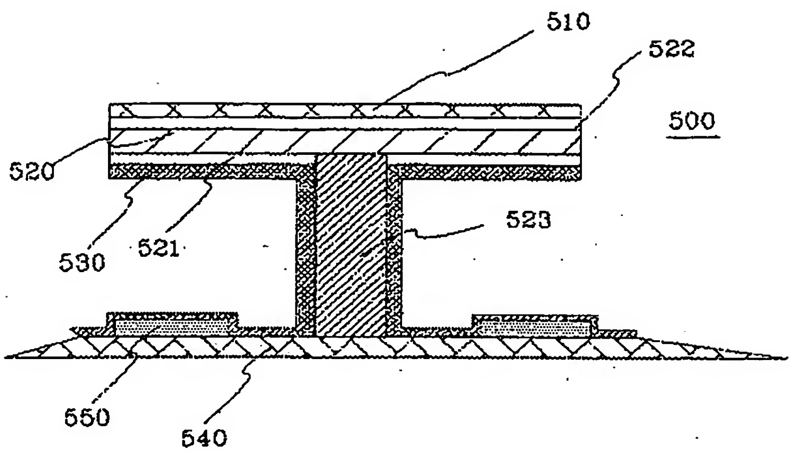


Fig. 5

[Drawing 6]

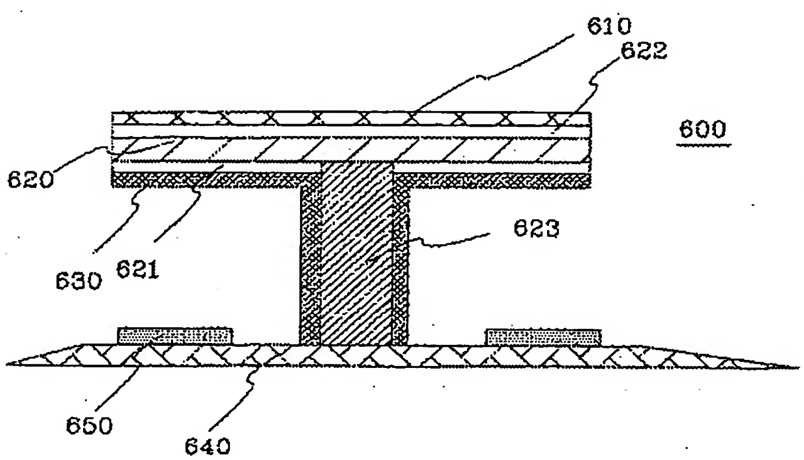


Fig. 6

[Drawing 7]

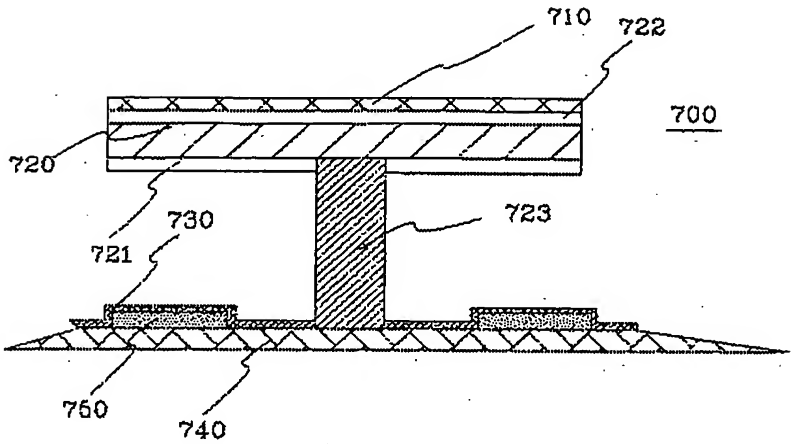


Fig. 7

[Drawing 8]

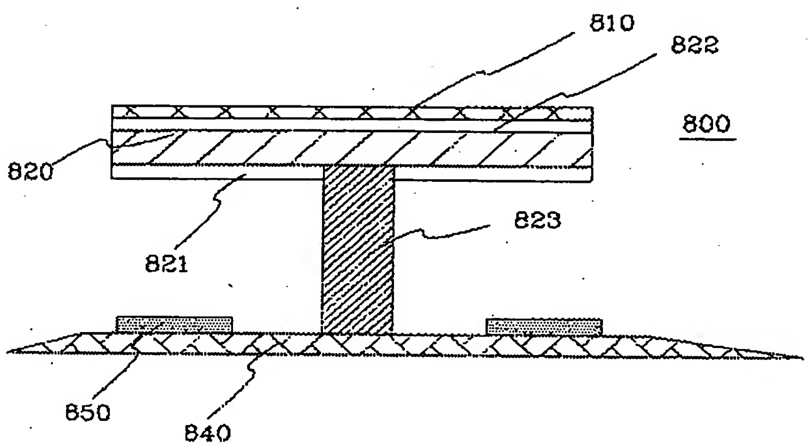


Fig. 8

[Drawing 9]

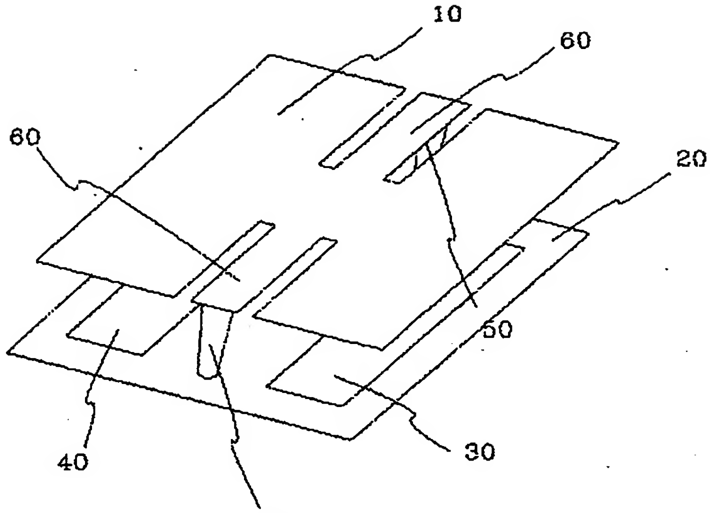


Fig. 9

[Written Amendment]
[Filing date]Heisei 17(2005) March 9 (2005.3.9)
[Amendment 1]
[Document to be Amended]Claims
[Item(s) to be Amended]Whole sentence
[Method of Amendment]Change
[The contents of amendment]
[Claim(s)]
[Claim 1]
It is how to improve resistance to damage caused by radiation in an optical minute electric machine system (MEMS) containing at least one movable modulation element, and said damage is produced from a low fluence and an addition pulse of electromagnetic radiation of short wavelength,
<u>In operating wavelength including forming at least one radiation resistance layer on the front-face said at least one movable modulation element side in which said radiation resistance layer is shorter than about 248 nm or it, it is reflexibility substantially,</u>
A described method.
[Claim 2]
In a method according to claim 1, said radiation resistance layer, An oxide (Hf_aO_b) of hafnium, fluoride of magnesium (Mg_eF_x), A described method containing at least one of fluoride (La_pF_x) of a lantern, an oxide ($aluminum_sO_t$) of aluminum, an oxide (Si_yO_x) of silicon, or fluorides (Li_kF_z) of lithium.
[Claim 3]
A described method with which said radiation resistance layer contains an oxide of hafnium, an oxide of aluminum, or an oxide of silicon in a method according to claim 1.
[Claim 4]
A described method with which said radiation resistance layer contains fluoride of magnesium, fluoride of calcium, or fluoride of lithium in a method according to claim 1.
[Claim 5]
A described method which is a said radiation resistance layer placing-layer by the side of a front face of said movable modulation element in a method according to claim 1.
[Claim 6]
A described method with which said placing radiation resistance layer is activated in a method according to claim 5.
[Claim 7]
A described method with which said placing radiation resistance layer comprises placing element boron and carbon in a method according to claim 6.
[Claim 8]
Including being the method according to claim 1 and forming further two or more radiation resistance layers, said two or more radiation resistance layers, a placing layer by which an oxide of hafnium, an oxide of aluminum, an oxide of silicon, fluoride of magnesium, fluoride of calcium, fluoride of lithium or boron, and carbon were activated, and ** -- a described method of at least one inside to include.
[Claim 9]

A described method in which said radiation resistance layer has a thickness of about 30 to 70 nm in a method according to claim 1.
[Claim 10]
A described method in which said radiation resistance layer has a thickness of about 2 to 50 nm in a method according to claim 1.
[Claim 11]
A described method in which said radiation resistance layer has a thickness of about 50 to 100 nm in a method according to claim 1.
[Claim 12]
A described method with which said movable modulation element contains aluminum in a method according to claim 1.
[Claim 13]
A described method with which said movable modulation element includes material of one or more of a silicon nitride, silicon, titanium, tantalum, or the tungsten in a method according to claim 1.
[Claim 14]
A described method in which said material composition of on a method according to claim 1 and as opposed to said radiation resistance layer is the average bulk composition from the upper part of said layer to the lower part of said layer.
[Claim 15]
A described method in which said material composition to one with said two or more radiation resistance layers arbitrary in a method according to claim 2 is the average bulk composition from the upper part of said layer to the lower part of said layer.
[Claim 16]
A described method which is the method according to claim 1 and includes forming further a reflecting layer containing one or more of aluminum, silver, and the gold before forming said radiation resistance layer.
[Claim 17]
A described method which said movable modulation element has the rear-face side, and includes forming at least one antireflection layer on said rear-face side further in a method according to claim 1.
[Claim 18]
A described method with which said antireflection layer contains CaF_2 or MgF_2 in a method according to claim 17.
[Claim 19]
A described method with which said antireflection layer contains fluoride of magnesium or calcium in a method according to claim 17.
[Claim 20]
A described method in which said antireflection layer has a thickness of about 15 to 80 nm in a method according to claim 17.
[Claim 21]
A described method in which said antireflection layer has a thickness of about 40 to 60 nm in a method according to claim 17.
[Claim 22]
A described method in which said antireflection layer has a thickness of about 60 to 80 nm in a method according to claim 17.
[Claim 23]
A described method with which said movable modulation element transmits electromagnetic radiation in a method according to claim 1.
[Claim 24]
In a method according to claim 23, said movable modulation element is a transparent described method substantially to wavelength of 248 nm or less.
[Claim 25]
A described method with which said movable modulation element contains an oxide of silicon in a method according to claim 23.
[Claim 26]
A described method with which said radiation resistance layer contains one layer in a method according to claim 23.
[Claim 27]
A described method with which said radiation resistance layer contains two or more layers in a method according to claim 23.
[Claim 28]
A described method with which said radiation resistance layer contains fluoride of magnesium or calcium in a method according to claim 23.
[Claim 29]
A described method in which said radiation resistance element is an oxide of two, aluminum beyond it, or silicon in a method according to claim 23.
[Claim 30]
A described method which is the method according to claim 1 and includes carrying out flattening of said front-face side further before forming said radiation resistance layer.
[Claim 31]
A described method with which said front-face side has good RMS surface smoothness from 2 nm after said flattening in a method according to claim 30.
[Claim 32]
A described method with which said front-face side has good RMS surface smoothness from 1 nm after said flattening in a method according to claim 30.
[Claim 33]
A described method with which said front-face side has good RMS surface smoothness from 0.5 nm after said flattening in a method according to claim 30.
[Claim 34]
A described method which contains CPM which uses an abrasive grain of a size in which said flattening is smaller than 300 nm in a method according to claim 30.
[Claim 35]
A described method with which said flattening contains CPM which uses an abrasive grain with a size of about 70 nm in a method according to claim 30.

[Claim 36]
A described method with which said flattening contains CPM which uses an abrasive grain with a size of about 50 nm in a method according to claim 30.
[Claim 37]
It is at least one movable modulation element of an optical minute electric machine system (MEMS).
The front-face side,
In operating wavelength including at least one radiation resistance layer on said front-face side in which said radiation resistance layer is shorter than about 248 nm or it, it is reflexibility substantially to radiation,
The above-mentioned movable modulation element.
[Claim 38]
The above-mentioned element which is transmission nature substantially in operating wavelength in the element according to claim 37 whose said movable modulation element and said radiation resistance layer are shorter than about 248 nm or it.
[Claim 39]
In the element according to claim 37, said radiation resistance layer, The above-mentioned element containing at least one of a hafnium acid ghost (HfO_2), magnesium fluoride (MgF_2), an aluminum oxide ($aluminum_2O_3$), a silica dioxide (SiO_2), or lithium fluorides (LiF_2).
[Claim 40]
A described method with which said radiation resistance layer contains an oxide of hafnium, an oxide of aluminum, or an oxide of silicon in a method according to claim 37.
[Claim 41]
A described method with which said radiation resistance layer contains fluoride of magnesium, fluoride of calcium, or fluoride of lithium in a method according to claim 37.
[Claim 42]
A described method which is a said radiation resistance layer placing-layer by the side of a front face of said movable modulation element in a method according to claim 37.
[Claim 43]
A described method which is a flat surface where said front-face side has 2 nm or better RMS in a method according to claim 37.
[Claim 44]
It is the element according to claim 37, and is a pan,
The rear-face side of said movable modulation element,
At least one antireflection layer formed on said rear-face side,
******, the above-mentioned element.
[Claim 45]
It is the element according to claim 43, and is a pan,
A non-movable substrate under said movable modulation element which said moving element combines in movable,
At least one antireflection layer formed in said a part of non-movable substrate,
******, the above-mentioned element.
[International Search Report]
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(74) Representative 100072040
A patent attorney ASAMURA, Hajime
(74) Representative 100102897
A patent attorney IKEDA, Yukihiro
(74) Representative 100088926
A patent attorney NAGANUMA, Teruo
(72) An inventor Sand SUTOREMU, torr BYORUN
Sweden, pix bow, and Van Bex Genn 56
(72) An inventor It is prodigal and they are bottle skiing, Thomas, and Jay.
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(72) An inventor Lung Brad, URURIKKU
Sweden, Melndal, ARUFUHEIDESUGATAN 12
(72) An inventor KUNASU, Christiane
The Federal Republic of Germany, Dresden, rhe NITSUERU MUERUVEKU 68
(72) An inventor Eberhardt, Qus
The Federal Republic of Germany, MORITSUBURUKU, Ham Walter SUGURUNDO 4
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(71)出願人 504095793
マイクロニック レーザー システムズ アクチボラゲット
スウェーデン国、タビイ、ニイトルブスベーゲン 9

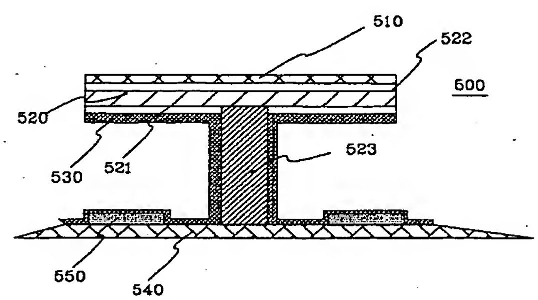
(71)出願人 505250029
フラウンホーファー ー ゲゼルシャフト ツル フェーデルング デル アンゲヴァントテン フォルシュング エー．ファオ．
ドイツ連邦共和国 80686 ミュンヘン、 ハンザシュトラーセ 27ツェー

(74)代理人 100066692
弁理士 浅村 皓

最終頁に続く

(54)【発明の名称】微小電気機械素子と共に使用される高エネルギー、低エネルギー密度の放射抵抗光学素子

(57)【要約】
本発明は、可動微小機械光学素子の放射抵抗を改良する方法及び素子を含む。特に、１平方センチメータ当たり１００マイクロジュールより小さいエネルギー密度の有パルス・レーザ・エネルギーに約２４８ｎｍ以下の波長において露光されることにより生じる、素子における表面及びバルク材料の変化を減少させるのに適した放射抵抗層が、可動微小機械光学素子に追加される。



【特許請求の範囲】
【請求項１】
少なくとも１つの可動変調素子を含む光学微小電気機械システム（ＭＥＭＳ）における放射によって引き起こされる損傷に対する抵抗を改良する方法であって、前記損傷は、低フルエンス、短波長の電磁放射の添加パルスから生じるものであって、
前記少なくとも１つの可動変調素子の前面側上に少なくとも１つの放射抵抗層を形成すること、
を含む、上記方法。
【請求項２】
請求項１に記載の方法において、前記放射抵抗層は、約２４８ｎｍあるいはそれより短い動作波長において実質的に反射性である、上記方法。
【請求項３】
請求項１に記載の方法において、前記放射抵抗層は、ハフニウムの酸化物（Hf_aO_b）、マグネシウムのフッ化物（Mg_eF_x）、ランタンのフッ化物（La_pF_x）、アルミニウムの酸化物（Al_sO_t）、シリコンの酸化物（Si_yO_x）、又はリチウムのフッ化物（Li_kF_z）のうち少なくとも１つを含む、上記方法。
【請求項４】
請求項１に記載の方法において、前記放射抵抗層は、ハフニウムの酸化物、アルミニウムの酸化物、又はシリコンの酸化物を含む、上記方法。
【請求項５】
請求項１に記載の方法において、前記放射抵抗層は、マグネシウムのフッ化物、カルシウムのフッ化物、又はリチウムのフッ化物を含む、上記方法。
【請求項６】
請求項１に記載の方法において、前記放射抵抗層は、前記可動変調素子の前面側における打込み層である、上記方法。
【請求項７】
請求項６に記載の方法において、前記打込み放射抵抗層は、活性化される、上記方法。
【請求項８】
請求項７に記載の方法において、前記打込み放射抵抗層は、打込み要素ホウ素および炭素から成る、上記方法。
【請求項９】
請求項１に記載の方法であってさらに、複数の放射抵抗層を形成することを含み、前記複数の放射抵抗層は、ハフニウムの酸化物、アルミニウムの酸化物、シリコンの酸化物、マグネシウムのフッ化物、カルシウムのフッ化物、リチウムのフッ化物、又はホウ素および炭素の活性化された打込み層、のうちの少なくとも１つ含む、上記方法。
【請求項１０】
請求項１に記載の方法において、前記放射抵抗層は、約３０ｎｍから７０ｎｍの厚さを持つ、上記方法。
【請求項１１】
請求項１に記載の方法において、前記放射抵抗層は、約２ｎｍから５０ｎｍの厚さを持つ、上記方法。
【請求項１２】
請求項１に記載の方法において、前記放射抵抗層は、約５０ｎｍから１００ｎｍの厚さを持つ、上記方法。
【請求項１３】
請求項１に記載の方法において、前記可動変調素子はアルミニウムを含む、上記方法。
【請求項１４】
請求項１に記載の方法において、前記可動変調素子は、ケイ素窒化物、シリコン、チタン、タンタル、あるいはタングステンのうちの１つあるいは複数の材料を含む、上記方法。

【請求項１５】

請求項１に記載の方法において、前記放射抵抗層に対する前記材料構成は、前記層の上部から前記層の下部への平均バルク構成である、上記方法。

【請求項１６】

請求項３に記載の方法において、前記複数の放射抵抗層の任意の１つに対する前記材料構成は、前記層の上部から前記層の下部への平均バルク構成である、上記方法。

【請求項１７】

請求項１に記載の方法であってさらに、前記放射抵抗層を形成するのに先立ち、アルミニウム、銀および金のうちの１つ又は複数を含む反射層を形成することを含む、上記方法。

【請求項１８】

請求項１に記載の方法において、前記可動変調素子は後面側を有し、さらに、少なくとも１つの反射防止層を前記後面側上に形成することを含む、上記方法。

【請求項１９】

請求項１８に記載の方法において、前記反射防止層はCaF_2又はMgF_2を含む、上記方法。

【請求項２０】

請求項１８に記載の方法において、前記反射防止層は、マグネシウム又はカルシウムのフッ化物を含む、上記方法。

【請求項２１】

請求項１８に記載の方法において、前記反射防止層は、約１５ｎｍから８０ｎｍの厚さを持つ、上記方法。

【請求項２２】

請求項１８に記載の方法において、前記反射防止層は、約４０ｎｍから６０ｎｍの厚さを持つ、上記方法。

【請求項２３】

請求項１８に記載の方法において、前記反射防止層は、約６０ｎｍから８０ｎｍの厚さを持つ、上記方法。

【請求項２４】

請求項１に記載の方法において、前記可動変調素子は電磁放射を伝送する、上記方法。

【請求項２５】

請求項２４に記載の方法において、前記可動変調素子は、２４８ｎｍ以下の波長に対して実質的に透明である、上記方法。

【請求項２６】

請求項２４に記載の方法において、前記可動変調素子はシリコンの酸化物を含む、上記方法。

【請求項２７】

請求項２４に記載の方法において、前記放射抵抗層は１つの層を含む、上記方法。

【請求項２８】

請求項２４に記載の方法において、前記放射抵抗層は複数の層を含む、上記方法。

【請求項２９】

請求項２４に記載の方法において、前記放射抵抗層は、マグネシウム又はカルシウムのフッ化物を含む、上記方法。

【請求項３０】

請求項２４に記載の方法において、前記放射抵抗素子は、２つ又はそれ以上のアルミニウムあるいはシリコンの酸化物である、上記方法。

【請求項３１】

請求項１に記載の方法であってさらに、前記放射抵抗層を形成するのに先立ち、前記前面側を平坦化することを含む、上記方法。

【請求項３２】

請求項３１に記載の方法において、前記前面側は、前記平坦化の後、２ｎｍより良いＲＭＳ平坦性を有する、上記方法。

【請求項３３】

請求項３１に記載の方法において、前記前面側は、前記平坦化の後、１ｎｍより良いＲＭＳ平坦性を有する、上記方法。

【請求項３４】

請求項３１に記載の方法において、前記前面側は、前記平坦化の後、０．５ｎｍより良いＲＭＳ平坦性を有する、上記方法。

【請求項３５】

請求項３１に記載の方法において、前記平坦化は、３００ｎｍより小さい大きさの砥粒を使用するＣＰＭを含む、上記方法。

【請求項３６】

請求項３１に記載の方法において、前記平坦化は、約７０ｎｍの大きさの砥粒を使用するＣＰＭを含む、上記方法。

【請求項３７】

請求項３１に記載の方法において、前記平坦化は、約５０ｎｍの大きさの砥粒を使用するＣＰＭを含む、上記方法。

【請求項３８】

光学微小電気機械システム（ＭＥＭＳ）の少なくとも１つの可動変調素子であって、

前面側と、

前記前面側の上の少なくとも１つの放射抵抗層、

を含む、上記可動変調素子。

【請求項３９】

請求項３８に記載の素子において、前記放射抵抗層は、約２４８ｎｍ又はそれより短い動作波長において、放射に対して実質的に反射性である、上記素子。

【請求項４０】

請求項３８に記載の素子において、前記可動変調素子及び前記放射抵抗層は、約２４８ｎｍ又はそれより短い動作波長において実質的に伝送性である、上記素子。

【請求項４１】

請求項３８に記載の素子において、前記放射抵抗層は、ハフニウム酸化物（HfO_2）、マグネシウムフッ化物（MgF_2）、アルミニウム酸化物（Al_2O_3）、二酸化ケイ素（SiO_2）、又はリチウムフッ化物（LiF_2）のうち少なくとも１つを含む、上記素子。

【請求項４２】

請求項３８に記載の方法において、前記放射抵抗層は、ハフニウムの酸化物、アルミニウムの酸化物、又はシリコンの酸化物を含む、上記方法。

【請求項４３】

請求項３８に記載の方法において、前記放射抵抗層は、マグネシウムのフッ化物、カルシウムのフッ化物、又はリチウムのフッ化物を含む、上記方法。

【請求項４４】

請求項３８に記載の方法において、前記放射抵抗層は、前記可動変調素子の前面側における打込み層である、上記方法。

【請求項４５】

請求項３８に記載の方法において、前記前面側は、２ｎｍ又はより良いＲＭＳを有する平坦面である、上記方法。

【請求項４６】

請求項３８に記載の素子であってさらに、

前記可動変調素子の後面側と、

前記後面側上に形成された少なくとも１つの反射防止層、

を含む、上記素子。

【請求項４７】
請求項４５に記載の素子であってさらに、
前記可動素子が可動的に結合する、前記可動変調素子の下の非可動基板と、
前記非可動基板の一部に形成された少なくとも１つの反射防止層、
を含む、上記素子。
【発明の詳細な説明】
【技術分野】
【０００１】
（発明の分野）
本発明は、可動微小機械光学素子の放射抵抗を改良する方法および素子を含む。特に、１平方センチメータ当たり１００マイクロジュールより小さいエネルギー密度の有パルス・レーザ・エネルギーに約２４８ｎｍ以下の波長において露光されることにより生じる、素子における表面およびバルク材料の変化を減少させるのに適した放射抵抗層が、可動微小機械光学素子に追加される。
【背景技術】
【０００２】
（発明の背景）
光学微小電気機械システム（ＭＥＭＳ）あるいは空間光変調器（ＳＬＭｓ）は今日、視聴者のための映像を生成するために、映画およびプレゼンテーション・プロジェクタおよびテレビにおいて使用されている。パターンは通常、プロジェクション・スクリーンあるいはビューイング・プレートのような広範囲の表面上に現れる。これらのアプリケーションにおいて、可視波長光（４００－８００ｎｍ）が使用されている。ＭＥＭＳはまた、光のビームを１つの光学的経路から他の光学的経路に向けるスイッチとして使用されている。スイッチング・アプリケーションにおいて、より短い波長である紫外光ではなく、可視波長の光が通常使用されている。
【０００３】
本発明者および彼らの同僚は、最近、ＳＬＭｓを半導体素子製造に含まれるマイクロリソグラフィ処理に適用した。ＳＬＭｓは、より微細でより小さく、そしてより高密度にパックされた画像を生成するために使用されている。小さく、高密度にパックされた画像を描写するには、紫外線スペクトル内あるいはそれより短い、短波長の光を使用することが必要である。静電活性化は、超小型鏡を偏向させるために使用される。力を発生させるために、電圧が２つの電極の間で生成される。１つの電極は静的であり、他の電極は、例えば可動超小型鏡のようなアクチュエータに取り付けられている。例えばマスク・ライティング・ツールあるいはチップ製造ツールにおいて使用される、アクチュエータのアレイを有するＳＬＭは、特定のパターンと共にロードされ、ここでアクチュエータは、電磁放射のビームを製作品上に中継あるいは伝送するときに、アドレスされた状態あるいはアドレスされていない状態にある。この中継された電磁放射のビームは、上記製作品上にプリントされるべきパターンのスタンプを含む。このパターンは、それぞれマスクあるいはチップ上にプリントされるべき、パターンの部分集合あるいは完全なパターンであってもよい。
【発明の開示】
【発明が解決しようとする課題】
【０００４】
従って、約２４８ｎｍあるいはそれより短い波長を含む、短波長の光でＳＬＭｓを使用する問題を理解し、ＭＥＭＳ素子の有用性および寿命を効果的に延ばしながら、ＳＬＭｓを短波長で使用するよう適合させる方法および素子を開発する機会が生じた。
【課題を解決するための手段】
【０００５】
（発明の概要）
本発明は、可動微小機械光学素子の放射抵抗を改良する方法および素子を含む。特に、

１平方センチメータ当たり１００マイクロジュールより小さいエネルギー密度の有パルス・レーザ・エネルギーに約２４８ｎｍ以下の波長において露光されることにより生じる、素子における表面およびバルク材料の変化を減少させるのに適した放射抵抗層が、可動微小機械光学素子に追加される。

【０００６】

（発明の詳細な説明）

以下の詳細な説明は、図１－９を参照して行われる。好ましい実施例は、本発明の技術を開示するために説明され、ここに定義される請求項の範囲を制限するものではない。この分野の技術者には、以下の説明に際して、多様な同等の変更が認識されるであろう。

【０００７】

マイクロリソグラフィＳＬＭｓは、非常に小さく精密な可動光変調素子のアレイ、あるいは鏡のような光学素子を使用する。反射光学素子は、１つの側において数ミクロンから数十ミクロンであってもよい。複数のこのような素子を含むＳＬＭアレイは、１つの側において１センチメータより小さいものから１つの側において数十センチメータにまでなることができる。光学素子の厚さは、１－２ミクロンあるいは３５０－７００ｎｍの厚さであってもよく、あるいはこれより薄くあるいは厚くてもよい。望ましい平坦性（単一の反射素子の山から谷の湾曲率）は、１６ミクロンにわたり４－１０ｎｍ程精密であってもよいし、より精密であってもよい。表面の平坦性および機械的安定性（エッジ・カールに対する抵抗を含む）の双方が要求されることがある。素子の望ましい寿命は、放射の１から１００億あるいは１０００億パルスおよび多数の機械的たわみであってもよい。素子は、望ましいマイクロリソグラフィ・パターンを作成するために調整されるからである。

【０００８】

視聴者のための画像を生成するために使用されるＳＬＭｓと比較すると、マイクロリソグラフィＳＬＭｓは、より高い光子当たりエネルギーを有するより短い波長の光を使用する。より高いエネルギーの光子は、光学素子の表面およびバルクの物理化学的性質を物質的に変化させるより高い能力を有する。開発の間に、短波長の光において、高エネルギー光子は光学素子の光学的性質を変化させることがあることが観察されている。一般に、一定のフルエンスにおける反射面の性質における光子当たりの純変化は、照射電磁放射の波長に反比例する。一般に、電磁放射の波長がより短いほど、光学素子の表面および／あるいはバルク性質における光子当たりの変化はより大きい。光学素子のバルクおよび材料の性質における結果としての変化は、不可逆であり累積的である。マイクロリソグラフィＳＬＭｓ光学素子の性質における変化は、望ましくなく不可逆である。変化が忠実度を減少させ、従って生成された画像の質を落とすからである。

【０００９】

反射光学素子は、アルミニウムのような、望ましい高反射率の材料から形成される。パルスを有する、照射高エネルギー光子は、５００Ｈｚより大きいパルス率および２４８ｎｍ以下の波長において、および１平方センチメータ当たり１００マイクロジュールより小さいエネルギー密度において、可動光学素子の表面から反射される。衝突する光子は、光学素子の表面およびバルク性質に相互に影響を与えることがある。

【００１０】

反射ＳＬＭの使用は、このようなＳＬＭをレーザ・パターン生成のために使用することに制限されない。請求項の範囲は、ここに特定されるようなエネルギー密度および波長におけるレーザに基づくパターン生成のためのこのような技術の使用外にある、他の可動および静的、反射および伝送的光学素子を含むよう意図されている。例として、走査鏡、通信のためのフォトニック・スイッチ、およびＭＥＭＳシャッタ・アレイがあるが、これらに限定されない。

【００１１】

予測することができる変化のタイプは、光学素子の表面およびバルク性質に大いに依存する。導電、絶縁および半導材料は、同じ波長およびフルエンスの光に露光された場合、反応が異なる。光学素子のバルクおよび表面性質における光子によって引き起こされた変

化は、直接あるいは間接的に測定することができる。鏡に対する物質的変化は、硬度、化学的構成、表面の粗さ、材料の損失、膜厚における変化、あるいは光学素子の形における変化によって直接量を測ることができる。鏡の光学的性質における変化は、反射率、正反射率あるいは非正反射率、明るさあるいはコントラストにおける変化を通して質を測ることができる。

【００１２】

ＳＬＭの光学素子を定義するために使用されるレジスト・パターニング処理は、環境への露出がそうであるように、その後に残余物質を残すことが観察されている。レジスト処理あるいは他の源からの残余炭素が、光学素子の表面上で観察されている。サンプル構造（いわゆる鏡付きサンプル）は、３５０ｎｍの厚さのアルミニウム／マグネシウム／シリコン合金膜をフォトレジスト上に含んでいた。これらのサンプル構造は、１６０℃において１２時間アニールされた。いわゆる“処理された”構造は、２４８ｎｍのレーザ光の９０００万、２．５ｍＪ／ｃｍ^2、２５ｎｓパルスに５００Ｈｚにおいて露光された。他のサンプル構造（いわゆる鏡無しサンプル）は、１０００ｎｍの厚さのアルミニウム／マグネシウム／シリコン合金膜をアニーリング無しで、単結晶シリコン基板上に有していた。いくつかの鏡無しサンプルは、低エネルギー密度、高エネルギー・レーザ・パルスに露光されることによって処理された。サンプル構造は分析された。

【００１３】

サンプルを分析すると、表面の上部の２つの単一層内において相対的に高い炭素の存在が示された。炭素の含有量は、表面より中約９ｎｍにおいて実質的に減少していた。アルミニウム酸化物の層は、炭素と混合したように見えた。予測されるように、合金の微粒が表面において観察され、スパッタ付着の副産物と考えられた。微粒は２０－２５ｎｍのオーダの大きさで現れた。いくつかの処理されたサンプルにおいて、合金の微粒は表面から放射され、きれいに除去され、隣接する微粒を変化させることなくそして少しも動かすことなく残し、２０－３０ナノメータの深さのホールを含む平らでない表面を残すように見えた。表面からの微粒の脱着は、Ｈ．ヘルバハン、Ｌ．ウィードマンおよびＨ．Ｓ．キム、“低フルエンスＵＶレーザ材料相互作用における光物理的処理および原子層処理への関連性”、アドバンスト・マテリアルス・フォー・オプティックス・アンド・エレクトロニクス、Ｖｏｌ．２、３１－４２ページ、４０（１９９３）の本発明とは関係のない実験結果と一致する。

【００１４】

処理済みと未処理の構造の表面硬度もまた比較された。ヒスティロン・トライボスコープＴＭ分析器によってかけられた力と、ＡＦＭを用いて分析された結果を組み合わせると、処理されたサンプルの表面は、分析調査による浸透により抵抗し、従って、処理されていない表面より硬いと考えられた。処理された鏡付きサンプルのＴＥＭ画像は、物理化学的に非同質で、炭素の多い、アルミニウム、酸素、マグネシウムおよびシリコンの混合であろうと考えられる膜を示した。材料（酸素および微粒）の損失と表面硬度の強化の組合せは、処理の後に鏡構造の１６ミクロンの幅の素子面にわたって観察された５－２０ｎｍの湾曲と関連していると推測された。

【００１５】

これらの観察から、そしてこれらの観察に一致して、約２４８ｎｍにおけるあるいはそれより短い波長に露光される予定の光学ＭＥＭＳの処理のための方法が開発された。平坦化バフ研磨は、鏡構造の下に位置するレジストから鏡をはずす前に鏡に適用されてもよく、より一般的には、短波長に露光される予定の光学ＭＥＭＳ構造に適用されてもよい。ＣＭＰバフ研磨は、表面の粗さを小さくするために、非常に小さい砥粒を使用することが望ましい。バフ研磨は、光学ＭＥＭＳの表面から微粒を取り除いて滑らかにするのに十分なように採用されてもよい。微粒は、反射光学素子の表面およびバルク性質への露光後の変化と関係があると考えられる。バフ研磨は、鏡の表面から微粒を除去するのに十分なように採用されてもよい。適当なｐＨおよび粘度、その他において、５０あるいは７０ｎｍの大きさの粒子を有するシリカを基本とするスラリーが役に立つと期待される。より一般的

には、粒子の大きさが３００ｎｍあるいはより小さい砥粒が役に立つ可能性がある。異なる研磨剤を使用する他のスラリーも同等によく役に立つかもしれない。ＡＴＭＩ、Ｉｎｃ．のＡＣＳＩグループによって開発され、商標名プラナ・ケム・ＯＳ・シリーズ・オクサイドＳＭＰスラリーの名で販売されているスラリーは、望ましい小さい粒子サイズを有している。これらのスラリーの構造は、米国特許第５，９９３，６８５号、金属膜を除去するための平坦化構成（１９９９年１１月３０日）、第６，２６７，９０９号、金属膜を除去するための平坦化構成（２００１年７月３１日）、および第６，３２２，６００号、内部層誘電膜を除去するための平坦化構成および方法（２００１年１１月２７日）に説明される研究に基づくと考えられる。また、光学ＭＥＭＳ表面の構成により、約５－３０、５－２０、５－１０、１０－２０、２０－３０、５０－１００ｎｍ、を含む範囲、あるいは５、１０、２０、３０、５０あるいは１００ｎｍあるいはそれ以下の材料を除去するバフ研磨を実行してもよい。バフ研磨の限界大きさは、表面構成によって変化する。表面の粗さは、原子間力顕微鏡を使用して観察および測定することができる。

【００１６】

図９は、可動微小光学素子の実施例を示している。可動光学素子は、空間光変調器（ＳＬＭ）アレイにおける鏡素子であってもよい。この鏡は、偏向角度の範囲を通して、あるいは二進数最大値あるいはゼロ偏向に偏向されてもよい。鏡素子の偏向は、入力信号の機能として、線形あるいは非線形であってもよい。

【００１７】

図９において、可動光学素子１０は一般に長方形であり、その中間部分の１つに沿って１組のねじり蝶番６０によって支えられている。可動光学素子は、任意の形であってもよく、例えば多角形、円形あるいは楕円形であってもよい。上記蝶番は、支持素子５０によって支持されている。可動微小素子１０、ねじり蝶番６０、および支持素子は、例えばアルミニウムあるいは異なる材料である、同じ材料から成っていてもよい。基板２０は、導電電極３０、４０を含む。電極２０、３０は、基板２０内に作られた回路（図示されていない）に接続している。電極の１つと上記光学素子との間に電位差をかけると、静電力が蓄積し、これにより上記可動光学素子が静電気的に引き付けられる（偏向される）。

【発明を実施するための最良の形態】

【００１８】

実施例１

図１は、超小型鏡構造１００の第１の実施例の断面図である。構造１００は、光学素子あるいは前面１２０、支持構造１２３、および基板１４０を含む。支持構造は、光学素子１２０を基板１４０に取り付けている。基板は、素子１２０を静電気的に引き付けるために使用される少なくとも１つの電極を含む。可動素子は、その前面において、放射抵抗コーティング１１０で層が作られている。放射抵抗層１１０は、実質的に反射性であってもよい。実質的に反射性の表面は、反射率が２０パーセントより大きいことが望ましいが、これに限定されない。この反射率水準は、可視範囲におけるよりも、高周波数／低波長においてより低い。前面１２０と接触する前にエネルギー密度を小さくすることによって、低フルエンス、高エネルギー光子によって引き起こされる、露光された反射光学素子１２０の表面およびバルク性質に対する光子によって引き起こされる損傷が減少する。低フルエンスは、１平方センチメータ当たり１００マイクロジュールより低い、１パルス当たりのフルエンスと特徴付けられる。鏡素子１２０は、アルミニウムから成っていてもよい。また、アルミニウムと共に、あるいはアルミニウム無しで、ケイ素窒化物、シリコン、チタン、タンタル、あるいはタングステンを含んでもよい。可動光学素子の基礎構造は、アルミニウム、ケイ素窒化物、シリコン、チタン、タンタル、タングステン、あるいは、わずかな量と見なされる弾性ヒステリシスで十分に偏向することができる、十分に延性のない、相互に層にされたあるいは合成された他の材料、のような材料から成ることができるが、これらに限定されない。反射層は、個別に図示されていないが、アルミニウム、銀、金、あるいはいくつかの他のより適した反射面を含んで付けることができる。

【００１９】

放射抵抗層１１０は、ハフニウム、シリコン、アルミニウムの酸化物；イットリウムあるいはスカンジウム；あるいはマグネシウム、カルシウム、ランタン、リチウム、モリブデン、ナトリウムおよびアルミニウム、ネオジム、ガドリニウムあるいはアルミニウムのフッ化物；モリブデンのケイ素化合物；あるいはまたホウ素の炭化物から成る、１つの層あるいは複数の層であってもよい。例えば、アルミニウムおよびシリコンの酸化物の４つから６つの交互の層を使用してもよい。他の実施例においては、多くの層、５０あるいは１００もの層を使用してもよい。多くの層を使用することは、アンジェラ・デュパレ、ステファン・ジャコブス＆ノーバート・カイザー、“基板表面および膜の粗さのＵＶスペクトル領域のための光学コーティングの質に対する影響”、ＳＰＩＥ　Ｖｏｌ．３１１０、５０９－５１６ページ、において異なる状況において言及されており、本文献は５１０ページにおいて、４９層を有するシステムに言及している。また、Ｎ．カイザー、Ｈ．ユーリグ、Ｕ．Ｂ．シャレンバーグ、Ｂ．アントン、Ｕ．カイザー、Ｋ．マーティン、Ｅ．エバ、“エキシマレーザのための高損傷閾値Al_2O_3／SiO_2誘電コーティング”、シン・ソリッド・フィルムス、Ｎｏ．２６０、８６－９２ページ（１９９５）、においても言及されており、これは８７ページにおいて２４層のシステムに言及している。放射抵抗層は、既知の付着およびイオン打込み技術によって付けてもよい。付着技術は、スパッタリング、ＣＶＤ、電子蒸着法、レーザ蒸着法、およびレーザあるいはプラズマ助長酸化を含む。

【００２０】

鏡の反射面は、望ましい放射抵抗コーティングの付着に先立ち、上記のように、化学的機械研磨（ＣＭＰ）あるいはいくつかの他のより適した表面スムージング技術によって平滑化することができる。可動光学素子の前面は、高度な平滑さを有することが望ましい。このことは、照射光子の表面に対する相互作用を非干渉にするのに役立つと考えられている。光学素子の表面の平滑さは、２ｎｍＲＭＳ（二乗平均の平方根）より小さくなければならず、１ｎｍＲＭＳより小さいことがより望ましく、０．５ｎｍＲＭＳより小さいことがさらに望ましい。

【００２１】

このような放射抵抗コーティングは、１０億を超過する多数の添加パルスから生じる反射性の損失あるいは損傷を、２４８ｎｍ以下の波長を有する低フルエンス光子に、実質的に減らすことが期待される。表面は、各添加パルスがあっても、より平坦なまま残ると期待される。

【００２２】

図１における実施例は、上記鏡素子１２０の後面上、上記支持構造１２３上、および上記少なくとも１つの電極１５０を含む下に位置する基板１４０上の、反射防止コーティング１３０を示している。反射防止コーティング１３０は、マグネシウムあるいはカルシウムのフッ化物、あるいはシリコンおよび／あるいはアルミニウムの酸化物、あるいは、使用される波長において反射防止性質を有するいくつかの他のより適したコーティングの、１つあるいは複数の層から成っていてもよい。反射防止コーティング１３０は、ＳＬＭの光学素子によって生成される反射された画像の忠実度の劣化の原因となることがある、ＳＬＭ素子の反射面の下における可能性のあるにせの反射を減少させる。さらに、このような放射抵抗コーティングの反射防止性質は、このような高エネルギーで短波長の光子に敏感であるかもしれない下に位置する回路への保護を提供することができる。

【００２３】

放射抵抗コーティングの厚さは、通常２－１５０ｎｍの範囲内にある。５－１００ｎｍの範囲内にあることが望ましく、１０－５０ｎｍの範囲内にあることがより望ましい。

【００２４】

反射防止コーティングの厚さは、通常１５－８０ｎｍの範囲内にある。１５－７０ｎｍの範囲内にあることが望ましく、２０－６０ｎｍの範囲内にあることがより望ましい。

【００２５】

図１における断面図と図９の等角投影図を比較すると、中央の垂直構造１２３は、光変

調構造１２０と同じ設置面積を持つ必要はないことが明らかである。つまり、ねじり蝶番６０は、どちらかの端において支持５０を持つよう形成されてもよい。多くの反射性および伝送性ジオメトリは、光変調構造１２０を支持するための多様な構造を持ちながら、本発明の応用から利益を得ることができる。

【００２６】

実施例２

図２は、本発明の超小型鏡構造２００の第２の実施例の断面図である。上記構造２００は、光学素子２２０、支持構造２２３、および基板２４０を含む。支持構造は、光学素子２２０を上記基板２４０に取り付けている。基板は、上記光学素子２２０を静電気的に引き付ける少なくとも１つの電極を含む。鏡素子は、放射抵抗コーティング２１０で覆われている。上記コーティングは、２４８ｎｍ以下の波長において低フルエンス光子に露光された場合の、反射素子２２０に対する、光子に引き起こされるバルクおよび表面における影響を実質的に減少させる。

【００２７】

反射光学素子２２０は、アルミニウムあるいはいくつかの他のより波長の適した反射コーティングあるいは基板から成っていてもよい。放射抵抗コーティング２１０は、ハフニウム、アルミニウムあるいはシリコンの酸化物、あるいはカルシウム、マグネシウムあるいはリチウムのフッ化物、あるいはホウ素の炭化物の、1つあるいは複数のものから成っていてもよい。プラチナ、パラジウム、ルテニウム、ロジウム、レニウム、オスミウム、あるいはイリジウムのような金属を、放射抵抗コーティングとしても使用することができる。単一あるいは多層コーティングを付着してもよい。放射抵抗コーティング２１０は、既知の付着（デポジション）および／あるいはこの分野では既知のイオン打込み技術によって付着してもよい。イオン打込みされた光学素子は、活性化され、この分野の技術者には周知の標準アニーリング手順を使用して、打込み後アニールによって放射抵抗としてもよい。コーティングされていない反射光学素子の上部表面は、放射抵抗コーティング２１０を形成する前に、平滑化されてもよい。

【００２８】

放射抵抗コーティング２１０は、明るさおよびコントラストの損失率を、１０億を超える添加露出から２４８ｎｍ以下の低フルエンス波長光へ、実質的に減少させる。放射抵抗コーティング２１０は、上記放射への抵抗を、数億パルスの範囲から数１０億パルスへ、同等の反射性の損失をもって増加させる。放射抵抗コーティングは、部分的には反射面に到達する光子の数を減少させる遮蔽を形成することによって、そして反射光学素子の原子および電子をその場に固定することによって、光子によって引き起こされる化学的および物理的変化から表面を保護する。

【００２９】

図２における実施例はまた、図１と同様に、反射防止コーティング２３０を上記鏡素子２２０の後面上に、および上記支持構造２２３の少なくとも一部の上に有するよう図示されているが、上記少なくとも１つの電極２５０を含む下に位置する基板２４０上には有しない。反射防止コーティング２３０は、マグネシウムあるいはカルシウムのフッ化物、あるいはシリコンおよび／あるいはアルミニウムの酸化物、あるいは、使用される波長における反射防止性質を有するいくつかの他のより適したコーティングの付着によって形成される、１つあるいは複数の層から成っていてもよい。上記反射防止コーティング２３０は、ＳＬＭの反射光学素子によって生成される反射された画像の忠実度の劣化の原因となることがある、ＳＬＭ素子の反射面の下におけるにせの反射を減少させる。さらに、このようなコーティングの反射防止性質は、このような高エネルギー、短波長の光子に敏感であるかもしれない下に位置する回路への保護を提供することができる。

【００３０】

実施例３

図３は、超小型鏡構造３００の第３の実施例を示している。本実施例において、反射防止コーティング３３０は、上記少なくとも１つの電極３５０を含む基板３４０のみを覆う

ように図示されている。上記鏡素子３２０の後面および上記支持構造は、上記反射防止コーティングに覆われていない。

【００３１】

実施例４

図４は、超小型鏡構造４００の第４の実施例を示している。上記構造４００は、他の実施例と同様に、鏡素子４２０、支持構造４２３、基板４４０、および少なくとも１つの電極４５０を含む。鏡素子４２０は、放射抵抗コーティング４１０に覆われている。本実施例において、反射防止コーティングは完全に省略されている。

【００３２】

図１、２、３および４に示される実施例において、鏡素子は、光学素子および構造素子を含むと考えてもよい。光学および構造素子は、アルミニウムあるいはアルミニウムの合金のような１つの基本材料から成っていてもよい。

【００３３】

実施例５

図５は本発明によるさらなる他の実施例を示しており、ここで、鏡構造素子５２０は、その前面５２２、その後面５２１、あるいはその両方の上において光学素子で覆われていてもよい。鏡構造素子５２０は、この場合、ケイ素窒化物、チタン、タンタル、タングステンのようなより延性のない材料、あるいは、シリコンあるいは類似する延性のない材料の合成物のような、わずかな偏向ヒステリシスを示すあるいは偏向ヒステリシスを示さない、いくつかの他のより適した延性のない材料から成ってもよい。

【００３４】

超小型鏡構造５００は、図１に示されている構造と非常に類似している。鏡構造素子５２０は、単一の元素構成から成っていてもよく、あるいは、アルミニウム、銅、およびシリコンの合金のような合金から成っていてもよい。さらに、構造素子５２０は、異なる材料の複数の層を含む、積重ねられた構造であってもよい。上記積重ねられた構造における材料は、一時的変形がパルス間の時間より長く持続する場合に、鏡のどんな一時的変形も効果的に最少にするように設計されてもよい。

【００３５】

光学素子５２２は、アルミニウム、アルミニウムの合金、銀、金、あるいは高反射率を有する任意の他の適当な材料であってもよい。

【００３６】

放射抵抗素子５１０は、上記のように１つの層あるいは複数の層であることができる。

【００３７】

アルミニウム超小型鏡は、炭化ホウ素で硬化されてもよい。炭化ホウ素は、ホウ素イオンおよび炭素イオンのイオン打込みによってアルミニウム超小型鏡に付けられてもよい。打込みの後、超小型鏡は、例えば熱アニールによってアニールされてもよい。

【００３８】

実施例６－８

図５における参照番号は、図１における参照番号に対応し、番号１００は番号５００に交換される。図６－８にも同様な規則が適用され、図６における特徴は図２に対応し、図７は図３に対応し、図８は図４に対応する。上記の説明は、図６－８において示される特徴に当てはまる。

【００３９】

本発明の１つの態様は、光学微小電気機械システム（ＭＥＭＳ）の、放射によって引き起こされる損傷に対する抵抗を改良するための方法である。ＭＥＭＳは、少なくとも１つの可動変調素子を含んでもよい。変調素子への損傷は、低フルエンス、短波長の電磁放射の添加パルスから生じてもよい。この状況において、低フルエンスは低エネルギー密度を意味する。本方法は、少なくとも１つの放射抵抗層を、少なくとも１つの可動変調素子の前面側上に形成することを含む。本方法によると、放射抵抗層は、約２４０ｎｍあるいはそれより短い動作波長において実質的に反射性であってもよい。放射抵抗層は、少なくと

も１つのハフニウム、アルミニウム、あるいはシリコンの酸化物を含んでもよい。放射抵抗層は、少なくとも１つのマグネシウム、ランタン、あるいはリチウムのフッ化物を含んでもよい。放射抵抗層は、酸化物とフッ化物の組合せを含んでもよい。また放射抵抗層は、打込み層を含んでもよい。この層は、可動変調素子の前面側上に打ち込まれるであろう。打込みは、ホウ素および炭素を含んでもよい。打込みは活性化されてもよい。熱アニーリングのようなアニーリングを、活性化のために使用してもよい。１つの放射抵抗層あるいは複数の放射抵抗層は、約３０ｎｍから７０ｎｍの厚さを持ってもよい。また、それは約２ｎｍから５０ｎｍあるいは５０から１００ｎｍの厚さを持ってもよい。可動変調素子は、アルミニウム、あるいはケイ素窒化物、シリコン、チタン、タンタル、あるいはタングステンの材料のうちの１つあるいは複数を含んでもよい。放射抵抗層に対する材料構成は、層の上部から層の下部への平均バルク構成であってもよい。反射層は、放射抵抗層を形成するのに先立ち形成されてもよい。反射層は、アルミニウム、銀、あるいは金のうちの１つあるいは複数を含んでもよい。可動変調素子は、後面側を有してもよく、方法はさらに、１つの反射防止層あるいは複数の反射防止層を、素子の後面側の上に形成することを含んでもよい。１つの反射防止層あるいは複数の反射防止層は、マグネシウムあるいはカルシウムのフッ化物を含んでもよい。１つの反射防止層あるいは複数の反射防止層の厚さは、１５から１００ｎｍ、あるいはまた、４０から６０ｎｍあるいは６０から８０ｎｍであってもよい。可動変調素子は、反射性あるいは伝送性であってもよい。この状況において、伝送性は、２４８ｎｍ以下の波長に対して実質的に透明であることを意味する。可動変調素子は、シリコン、シリコンの酸化物あるいはアルミニウムあるいはアルミニウムの酸化物を含んでもよい。本実施例の他の態様は、放射抵抗層を形成するのに先立ち、可動変調素子の前面側を平坦化してもよいことである。平坦化の結果は、２ｎｍより良い二乗平均の平方根平坦性であってもよく、１ｎｍより良いことが望ましく、素子の表面にわたって０．５ｎｍより良いことがより望ましい。この状況において、素子は、幅が約１６ミクロンであってもよい。平坦化は、約７０ｎｍあるいは約５０ｎｍのような、３００ｎｍより小さい大きさの砥粒を使用して実行してもよい。ここに説明される素子および態様は、多様な有用な組合せに組み合わせることができる。

【００４０】

上記の方法に対応して、その結果としての素子が製造される。本発明の１つの実施例は、前面側および前面側上の少なくとも１つの放射抵抗層を含む光学ＭＥＭＳの少なくとも１つの可動変調素子である。放射抵抗層は、２４８ｎｍあるいはそれより短い波長における放射に対して実質的に反射性であってもよい。放射抵抗層は、ここに説明される構成のうち任意のものを含んでもよい。素子の平坦性特性は、方法において説明されたものであってもよい。放射抵抗層は、支持非可動基板上に、可動変調素子の後面上に、あるいはこれらの双方の上に形成された１つあるいは複数の反射防止層と組み合わせてもよい。

【００４１】

本発明は、上に詳細に説明した好ましい実施例および例示を参照して開示されているが、これらの例示は本発明の範囲を制限するものではないことが理解される。上に開示された技術の変更および組合せは、この分野の技術者には容易に考え付くと考えられる。このような変更および組合せは、本発明および以下の請求項の範囲内にあると見なされるであろう。さらに、好ましい実施例は、可動反射ＳＬＭ光学素子およびデバイスを参照して説明されている。この分野の技術者には、伝送ＳＬＭのような反射ＳＬＭ以外のＭＥＭＳ構造も、本発明の態様から利益を得ることができることを理解されたい。伝送ＳＬＭｓに対しては、放射抵抗層は伝送構造上に形成され、本質的に反射性ではないように選択されてもよい。例えば、反射防止層は、伝送構造の前面あるいは後面側上に形成されてもよい。

【図面の簡単な説明】

【００４２】

【図１】本発明のＭＥＭＳ構造の第１の実施例の断面図である。

【図２】本発明のＭＥＭＳ構造の第２の実施例の断面図である。

【図３】本発明のＭＥＭＳ構造の第３の実施例の断面図である。

【図４】本発明のＭＥＭＳ構造の第４の実施例の断面図である。
【図５】本発明のＭＥＭＳ構造の第５の実施例の断面図である。
【図６】本発明のＭＥＭＳ構造の第６の実施例の断面図である。
【図７】本発明のＭＥＭＳ構造の第７の実施例の断面図である。
【図８】本発明のＭＥＭＳ構造の第８の実施例の断面図である。
【図９】超小型鏡構造の一例の等角投影図である。

【図１】

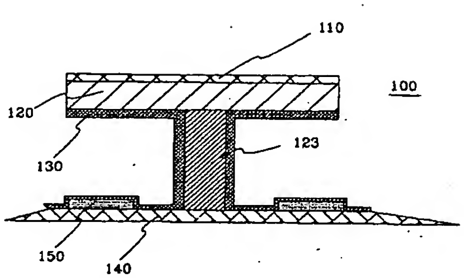


Fig. 1

【図２】

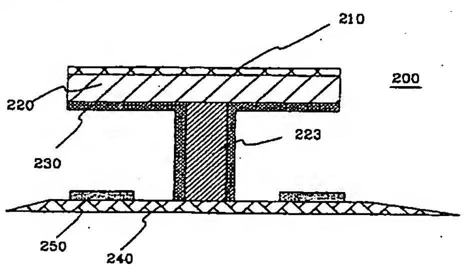


Fig. 2

【図３】

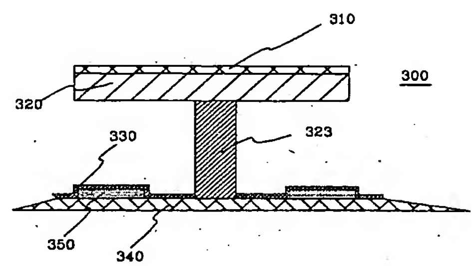


Fig. 3

【図４】

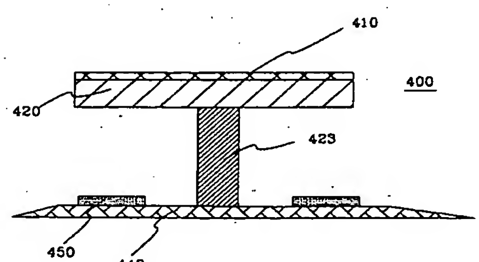


Fig. 4

【図５】

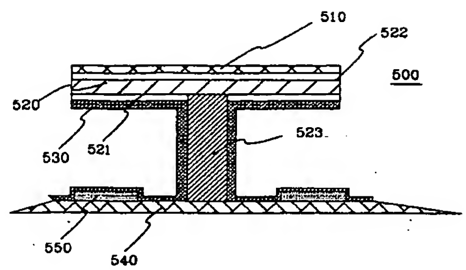


Fig. 5

【図６】

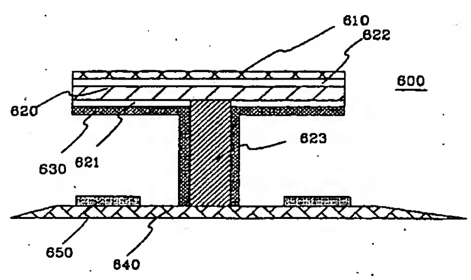


Fig. 6

【図７】

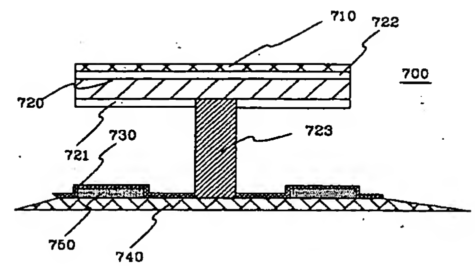


Fig. 7

【図８】

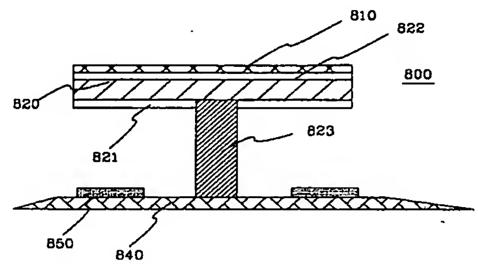


Fig. 8

【図９】

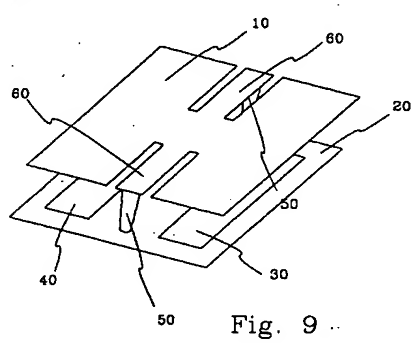


Fig. 9

【手続補正書】
【提出日】平成17年3月9日(2005.3.9)
【手続補正1】
【補正対象書類名】特許請求の範囲
【補正対象項目名】全文
【補正方法】変更
【補正の内容】
【特許請求の範囲】
【請求項1】
少なくとも1つの可動変調素子を含む光学微小電気機械システム(MEMS)における放射によって引き起こされる損傷に対する抵抗を改良する方法であって、前記損傷は、低フルエンス、短波長の電磁放射の添加パルスから生じるものであって、
前記少なくとも1つの可動変調素子の前面側上に少なくとも1つの放射抵抗層を形成することを含み、前記放射抵抗層は、約248nm又はそれより短い動作波長において実質的に反射性である、
上記方法。
【請求項2】
請求項1に記載の方法において、前記放射抵抗層は、ハフニウムの酸化物(Hf_aO_b)、マグネシウムのフッ化物(Mg_eF_x)、ランタンのフッ化物(La_pF_x)、アルミニウムの酸化物(Al_sO_t)、シリコンの酸化物(Si_yO_x)、又はリチウムのフッ化物(Li_kF_z)のうち少なくとも1つを含む、上記方法。
【請求項3】
請求項1に記載の方法において、前記放射抵抗層は、ハフニウムの酸化物、アルミニウムの酸化物、又はシリコンの酸化物を含む、上記方法。
【請求項4】
請求項1に記載の方法において、前記放射抵抗層は、マグネシウムのフッ化物、カルシウムのフッ化物、又はリチウムのフッ化物を含む、上記方法。
【請求項5】
請求項1に記載の方法において、前記放射抵抗層は、前記可動変調素子の前面側における打込み層である、上記方法。
【請求項6】
請求項5に記載の方法において、前記打込み放射抵抗層は、活性化される、上記方法。
【請求項7】
請求項6に記載の方法において、前記打込み放射抵抗層は、打込み要素ホウ素および炭素から成る、上記方法。
【請求項8】
請求項1に記載の方法であってさらに、複数の放射抵抗層を形成することを含み、前記複数の放射抵抗層は、ハフニウムの酸化物、アルミニウムの酸化物、シリコンの酸化物、マグネシウムのフッ化物、カルシウムのフッ化物、リチウムのフッ化物、又はホウ素および炭素の活性化された打込み層、のうちの少なくとも1つ含む、上記方法。
【請求項9】
請求項1に記載の方法において、前記放射抵抗層は、約30nmから70nmの厚さを持つ、上記方法。
【請求項10】
請求項1に記載の方法において、前記放射抵抗層は、約2nmから50nmの厚さを持つ、上記方法。
【請求項11】
請求項1に記載の方法において、前記放射抵抗層は、約50nmから100nmの厚さを持つ、上記方法。
【請求項12】

請求項１に記載の方法において、前記可動変調素子はアルミニウムを含む、上記方法。
【請求項１３】
請求項１に記載の方法において、前記可動変調素子は、ケイ素窒化物、シリコン、チタン、タンタル、あるいはタングステンのうちの１つあるいは複数の材料を含む、上記方法。
【請求項１４】
請求項１に記載の方法において、前記放射抵抗層に対する前記材料構成は、前記層の上部から前記層の下部への平均バルク構成である、上記方法。
【請求項１５】
請求項２に記載の方法において、前記複数の放射抵抗層の任意の１つに対する前記材料構成は、前記層の上部から前記層の下部への平均バルク構成である、上記方法。
【請求項１６】
請求項１に記載の方法であってさらに、前記放射抵抗層を形成するのに先立ち、アルミニウム、銀および金のうちの１つ又は複数を含む反射層を形成することを含む、上記方法。
【請求項１７】
請求項１に記載の方法において、前記可動変調素子は後面側を有し、さらに、少なくとも１つの反射防止層を前記後面側上に形成することを含む、上記方法。
【請求項１８】
請求項１７に記載の方法において、前記反射防止層はCaF_2又はMgF_2を含む、上記方法。
【請求項１９】
請求項１７に記載の方法において、前記反射防止層は、マグネシウム又はカルシウムのフッ化物を含む、上記方法。
【請求項２０】
請求項１７に記載の方法において、前記反射防止層は、約１５ｎｍから８０ｎｍの厚さを持つ、上記方法。
【請求項２１】
請求項１７に記載の方法において、前記反射防止層は、約４０ｎｍから６０ｎｍの厚さを持つ、上記方法。
【請求項２２】
請求項１７に記載の方法において、前記反射防止層は、約６０ｎｍから８０ｎｍの厚さを持つ、上記方法。
【請求項２３】
請求項１に記載の方法において、前記可動変調素子は電磁放射を伝送する、上記方法。
【請求項２４】
請求項２３に記載の方法において、前記可動変調素子は、２４８ｎｍ以下の波長に対して実質的に透明である、上記方法。
【請求項２５】
請求項２３に記載の方法において、前記可動変調素子はシリコンの酸化物を含む、上記方法。
【請求項２６】
請求項２３に記載の方法において、前記放射抵抗層は１つの層を含む、上記方法。
【請求項２７】
請求項２３に記載の方法において、前記放射抵抗層は複数の層を含む、上記方法。
【請求項２８】
請求項２３に記載の方法において、前記放射抵抗層は、マグネシウム又はカルシウムのフッ化物を含む、上記方法。
【請求項２９】
請求項２３に記載の方法において、前記放射抵抗素子は、２つ又はそれ以上のアルミニ

ウムあるいはシリコンの酸化物である、上記方法。
【請求項３０】
請求項１に記載の方法であってさらに、前記放射抵抗層を形成するのに先立ち、前記前面側を平坦化することを含む、上記方法。
【請求項３１】
請求項３０に記載の方法において、前記前面側は、前記平坦化の後、２ｎｍより良いＲＭＳ平坦性を有する、上記方法。
【請求項３２】
請求項３０に記載の方法において、前記前面側は、前記平坦化の後、１ｎｍより良いＲＭＳ平坦性を有する、上記方法。
【請求項３３】
請求項３０に記載の方法において、前記前面側は、前記平坦化の後、０．５ｎｍより良いＲＭＳ平坦性を有する、上記方法。
【請求項３４】
請求項３０に記載の方法において、前記平坦化は、３００ｎｍより小さい大きさの砥粒を使用するＣＰＭを含む、上記方法。
【請求項３５】
請求項３０に記載の方法において、前記平坦化は、約７０ｎｍの大きさの砥粒を使用するＣＰＭを含む、上記方法。
【請求項３６】
請求項３０に記載の方法において、前記平坦化は、約５０ｎｍの大きさの砥粒を使用するＣＰＭを含む、上記方法。
【請求項３７】
光学微小電気機械システム（ＭＥＭＳ）の少なくとも１つの可動変調素子であって、
前面側と、
前記前面側の上の少なくとも１つの放射抵抗層、を含み、前記放射抵抗層は、約２４８ｎｍあるいはそれより短い動作波長において、放射に対して実質的に反射性である、
上記可動変調素子。
【請求項３８】
請求項３７に記載の素子において、前記可動変調素子及び前記放射抵抗層は、約２４８ｎｍ又はそれより短い動作波長において実質的に伝送性である、上記素子。
【請求項３９】
請求項３７に記載の素子において、前記放射抵抗層は、ハフニウム酸化物（HfO_2）、マグネシウムフッ化物（MgF_2）、アルミニウム酸化物（Al_2O_3）、二酸化ケイ素（SiO_2）、又はリチウムフッ化物（LiF_2）のうち少なくとも１つを含む、上記素子。
【請求項４０】
請求項３７に記載の方法において、前記放射抵抗層は、ハフニウムの酸化物、アルミニウムの酸化物、又はシリコンの酸化物を含む、上記方法。
【請求項４１】
請求項３７に記載の方法において、前記放射抵抗層は、マグネシウムのフッ化物、カルシウムのフッ化物、又はリチウムのフッ化物を含む、上記方法。
【請求項４２】
請求項３７に記載の方法において、前記放射抵抗層は、前記可動変調素子の前面側における打込み層である、上記方法。
【請求項４３】
請求項３７に記載の方法において、前記前面側は、２ｎｍ又はより良いＲＭＳを有する平坦面である、上記方法。
【請求項４４】
請求項３７に記載の素子であってさらに、

前記可動変調素子の後面側と、
前記後面側上に形成された少なくとも１つの反射防止層、
を含む、上記素子。

【請求項４５】
請求項４３に記載の素子であってさらに、
前記可動素子が可動的に結合する、前記可動変調素子の下の非可動基板と、
前記非可動基板の一部に形成された少なくとも１つの反射防止層、
を含む、上記素子。

【国際調査報告】

1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 2003/002025

A. CLASSIFICATION OF SUBJECT MATTER

IPC7: G02B 1/10 // G02B 26/08
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC7: G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,X	US 2003016337 A1 (DUNCAN, W M ET AL), 23 January 2003 (23.01.2003), [0001]-[0007] -- -------	1,38

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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10 March 2004	12 -03- 2004
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Fredrik Wahlin /LR Telephone No. +46 8 782 25 00

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(74)代理人 100072040
弁理士 浅村 皓
(74)代理人 100102897
弁理士 池田 幸弘
(74)代理人 100088926
弁理士 長沼 暉夫
(72)発明者 サンドストレム、トルビョルン
スウェーデン国、ピクスボー、バンベーゲン　５６
(72)発明者 グレビンスキー、トマス、ジェイ
アメリカ合衆国、カリフォルニア、アラモ、シドニー　２３０
(72)発明者 ダウデルステドト、ウルリケ
ドイツ連邦共和国、ドレスデン、フォーシュテライシュトラーセ　１３デー
(72)発明者 リュングブラッド、ウルリック
スウェーデン国、メルンダル、アルフヘイデスガタン　１２
(72)発明者 クナス、クリスティアン
ドイツ連邦共和国、ドレスデン、レーニツェル　ムエルヴェク　６８
(72)発明者 エベラール、クース
ドイツ連邦共和国、モリツブルク、アム　ヴァルテルスグルンド　４

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